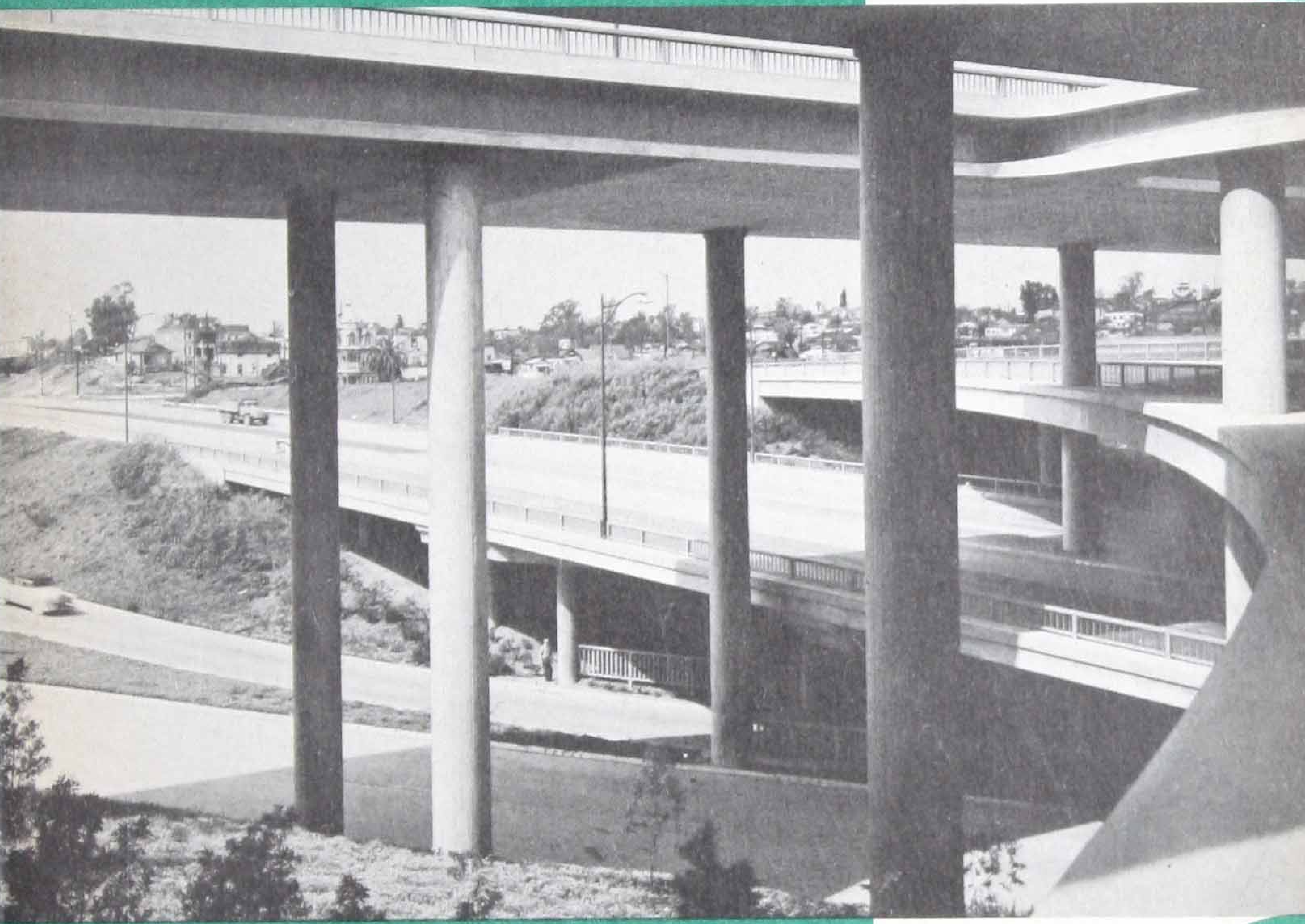
PORTLAND CEMENT ASSOCIATION



cement and concrete reference book

1956-1957

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33 West Grand Avenue
Chicago 10, Illinois

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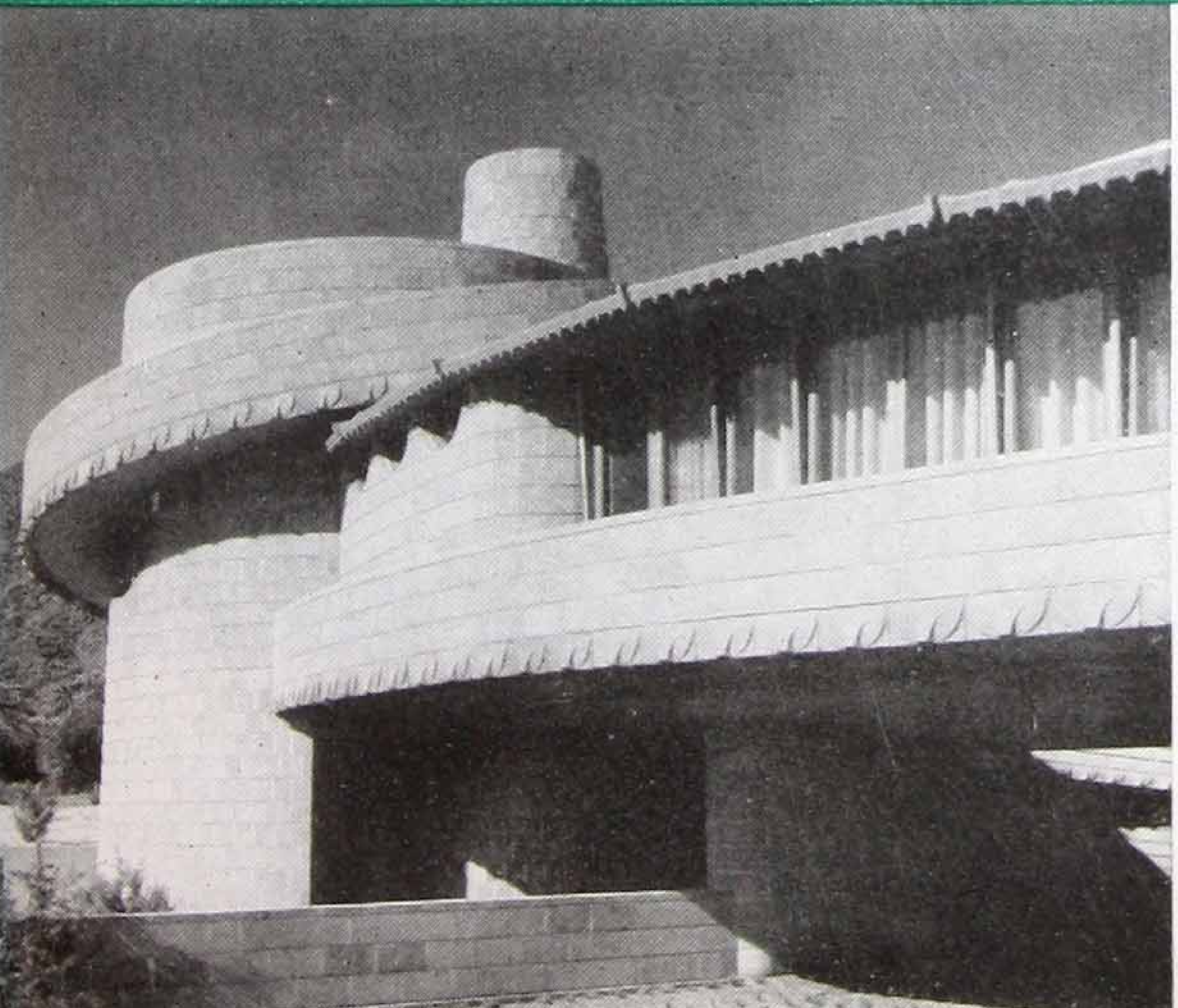


preface

THE information in these pages has been assembled from authoritative sources by the Portland Cement Association, a national organization whose activities are limited to scientific research, the development of new or improved products and methods, technical service, promotion and educational effort (including safety work), and are primarily designed to improve and extend the uses of portland cement and concrete. The manifold program of the Association and its varied services to cement users are made possible by the financial support of more than 70 member companies in the United States and Canada, engaged in the manufacture and sale of a very large proportion of all portland cement used in these two countries.

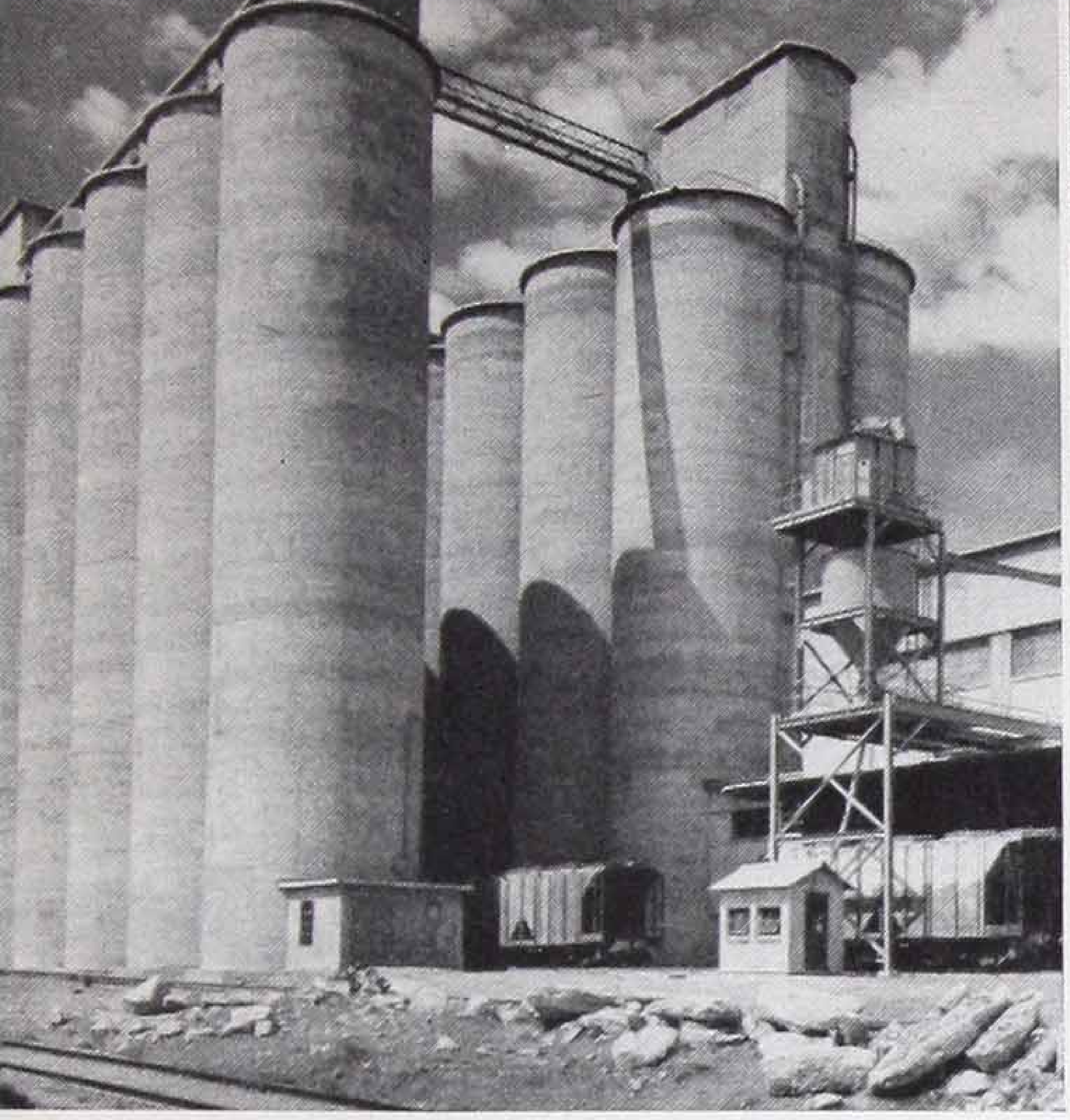
Additional information on portland cement and concrete and their uses may be secured at the General Office of the Portland Cement Association or from any of its district offices listed below. A list of member companies may be found on page 112.

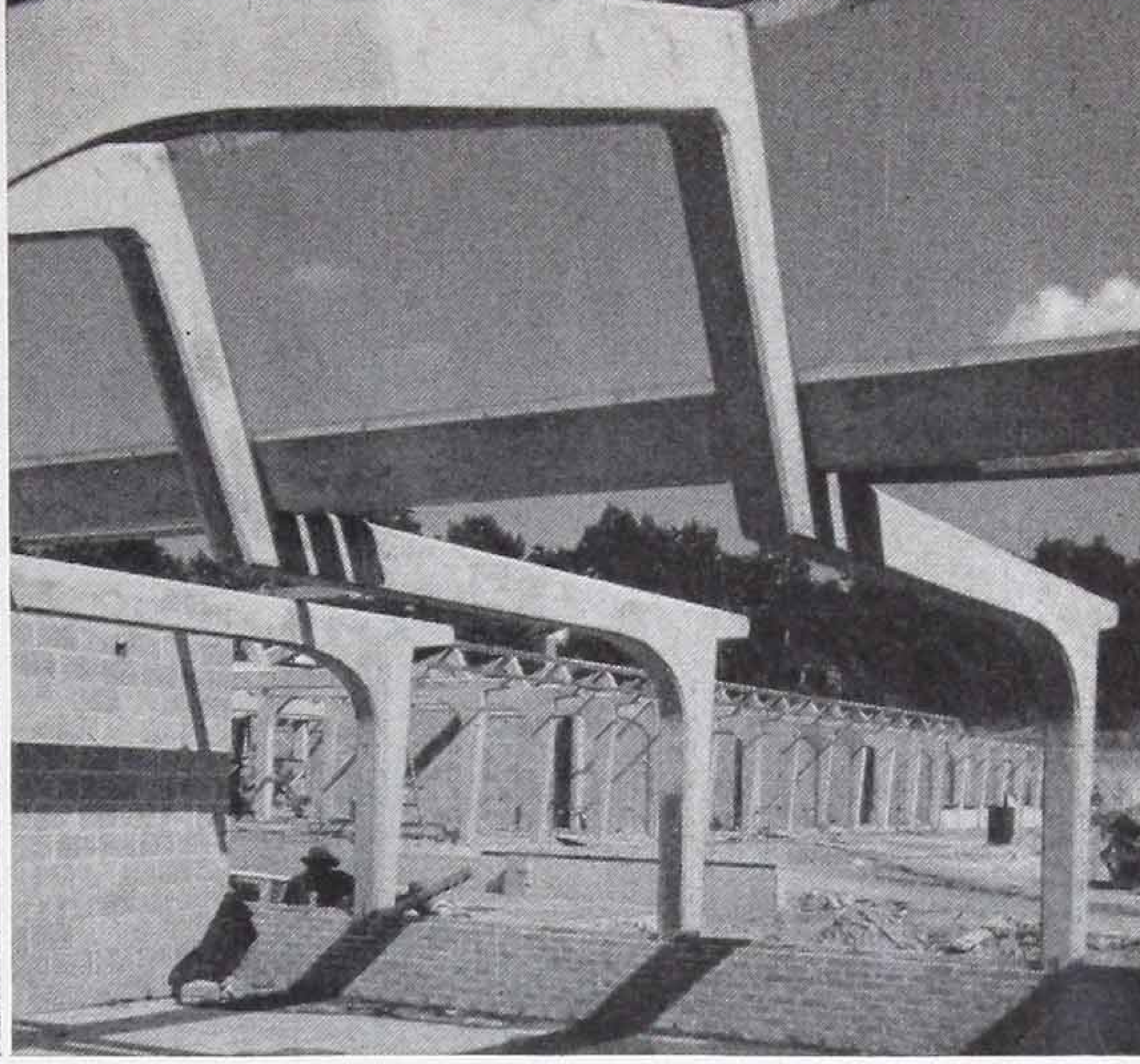
Portland Cement Association

33 West Grand Avenue, Chicago 10, Illinois

District Offices

Atlanta, Ga.
Austin, Texas
Baltimore, Md.
Birmingham, Ala.
Boston, Mass.
Chicago, Ill.
Columbus, Ohio
Denver, Colo.
Des Moines, Iowa
Helena, Mont.
Indianapolis, Ind.
Kansas City, Mo.
Lansing, Mich.
Los Angeles, Calif.
Louisville, Ky.
Memphis, Tenn.
Milwaukee, Wis.
Minneapolis, Minn.
New Orleans, La.
New York, N.Y.
Oklahoma City, Okla.
Omaha, Neb.
Orlando, Fla.
Philadelphia, Pa.
Portland, Maine
Richmond, Va.
Salt Lake City, Utah
Seattle, Wash.
St. Louis, Mo.
Trenton, N.J.
Vancouver, B.C., Canada
Washington, D.C.





how the editor can use this book

The Cement and Concrete Reference Book is a compilation of interesting facts about the history, manufacture and uses of portland cement and concrete. Portland cement has a great variety of uses—more than any other structural material in the construction field—and contributes in many ways to the health, safety and welfare of every citizen.

Because cement and concrete are so widely used and touch the public interest at so many points, this reference guide can be as useful to the small town weekly as to the large-circulation general magazine. In addition to factual material on specific topics, the Reference Book contains a great deal of general information on cement and concrete that is readily adaptable to local news events or special feature articles.

General topics covered are listed by title of article in the Table of Contents. At the beginning of Part A (which includes information on the work of the Portland Cement Association, the history and manufacture of portland cement, and the making of concrete) and again at the beginning of Part B (which covers the uses of cement and concrete), articles contained in each section are briefed in a few sentences for ready reference. Tables and charts are also listed in the Table of Contents.

Photographs and drawings in this book—along with thousands of others on the general subject of portland cement and concrete—are available for free use of editors and writers in the United States and Canada. Additional information may also be obtained by writing the Portland Cement Association, 33 West Grand Ave., Chicago 10, Ill.

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portland cement industry,

concrete and pca

Air-Entrained Concrete (page 24) . . .
is probably the most important development of concrete research in a generation. Air-entrained concrete is produced through the use of air-entraining portland cement—or by the introduction of air-entraining agents under careful engineering supervision as the concrete is mixed on the job. This article tells what air-entrained concrete is, describes its many applications, and explains why it is highly resistant to severe frost action and prevents surface scaling where chemicals are used to melt pavement ice.

Portland Cement Association, What It Is and What It Does (page 26) . . .
outlines the organization and objectives of the Portland Cement Association. Established with its main offices in Chicago since 1916, the Association is a national organization to improve and extend the uses of portland cement and concrete. This article describes how the Association's objectives are accomplished through the coordinated efforts of its large Research and Development Laboratories near Chicago, its various promotion bureaus in the General Office in Chicago, and its staff of more than 350 field engineers, architects and farm construction specialists working out of 32 district offices and serving cement users in 46 states, the District of Columbia and British Columbia.

Cement and Concrete Research (page 28) . . .
tells how the constant scientific research carried on—both in the laboratory and the field—by the Portland Cement Association and its members in the United States and Canada has multiplied the uses of portland cement and concrete, increased its durability and lengthened the service life of countless concrete structures that every day contribute to the national welfare.

Educational Program (page 32) . . .
describes the Portland Cement Association's wide range of informative literature and motion pictures, its educational advertising, and its participation in public lectures, demonstrations, technical clinics and personal field consultations. All of these activities contribute to an educational program designed to shorten the lag between research findings and practical application of technical advances in the uses of portland cement and concrete.

Safety Record of the Cement Industry (page 34) . . .
explains the safety program of the members of the Portland Cement Association, who have made an enviable record in the face of hazards involved in quarrying, mining and blasting, and in the use of high-voltage electric current and of some of the world's largest moving machinery. In 30 years Portland Cement Association member-company plants have operated the equivalent of 1,092 accident-free years, a safety record believed to be unequaled.

early history and development of portland cement

EVER since man first started to build, he has sought a material that would bind stones into a solid, formed mass. The Assyrians and Babylonians used clay for this purpose, and the Egyptians advanced to the discovery of lime and gypsum mortar as a binding agent for building such structures as the Pyramids. The Greeks made further improvements, and finally the Romans developed a cement that produced structures of remarkable durability.

Most of the foundations of buildings in the Forum in Rome were a form of concrete, placed to a depth of as much as 12 ft. The great Roman baths built about 27 B.C., the Colosseum, and the huge Basilica of Constantine are examples of early Roman architecture in which cement mortar was used.

The secret of Roman success in making cement was in mixing slaked lime with a volcanic ash from Mount Vesuvius, called pozzolana, which produced a cement capable of hardening under water.

During the Middle Ages this art was lost, and it was not until the scientific spirit of inquiry revived in the eighteenth century that men rediscovered the secret of cement that would harden under water—known as hydraulic cement.

Repeated structural failure of the Eddystone lighthouse off the coast of Cornwall, England, led a British engineer named John Smeaton to conduct experiments with mortars in both fresh and salt water. These tests led to his discovery in 1756 that lime made from limestone containing a considerable proportion of clay would harden under water. Making use of this discovery, he rebuilt the Eddystone lighthouse in 1759; his structure stood for 126 years before replacement was necessary.

Other men experimenting in the field of cement during the period from 1756 to 1830 were L. J. Vicat and Lesage in France and Joseph Parker and James Frost in England.

Joseph Aspdin Patent

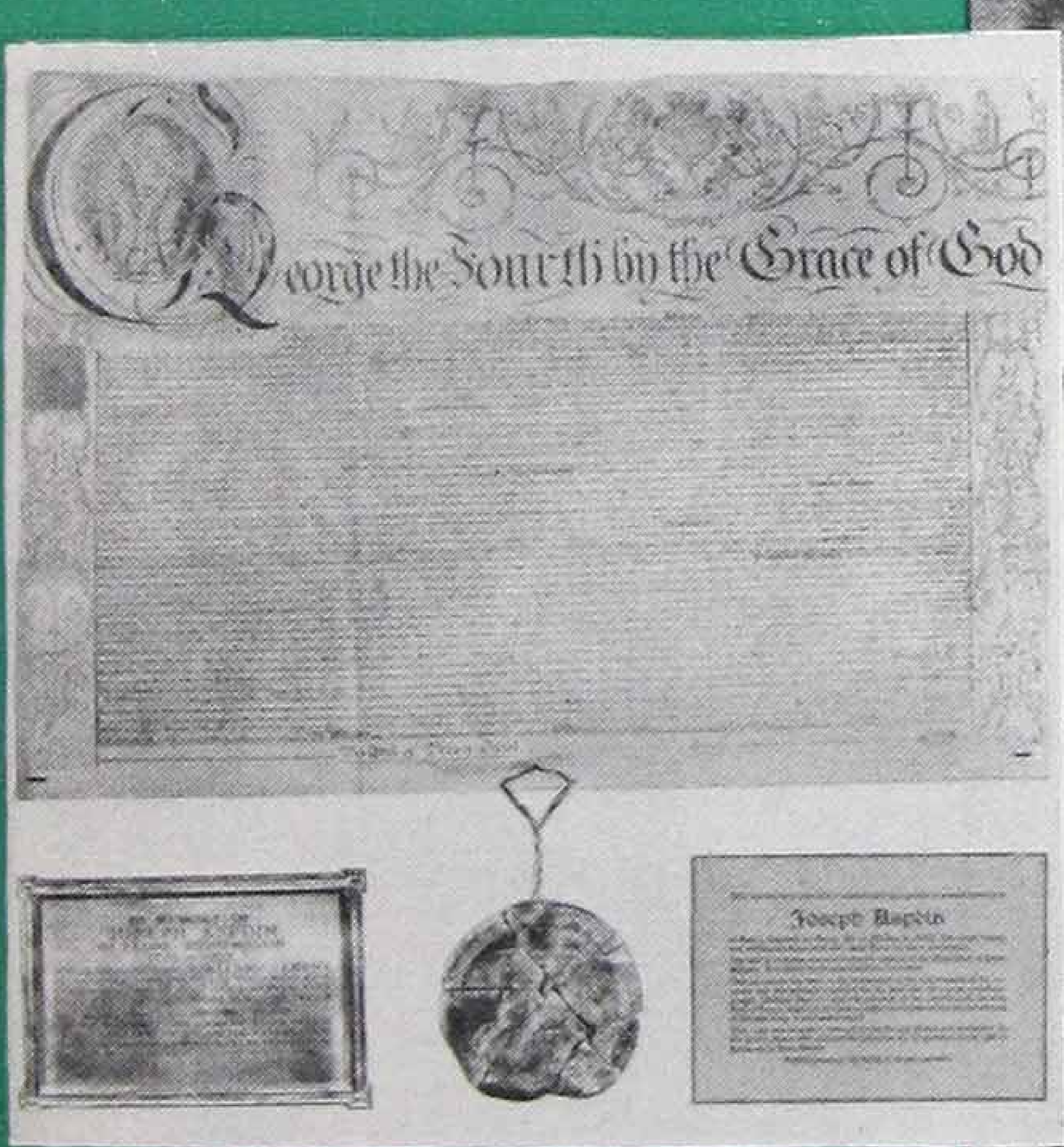
In 1824 a bricklayer and mason in Leeds, England, named Joseph Aspdin took out a patent on a hydraulic cement, which he called "portland" cement because it resembled in color the stone quarried on the Isle of Portland off the British coast. Aspdin's greatest contribution was his method of carefully proportioning limestone and clay, pulverizing them and burning the mixture into clinker, which was then ground into finished cement. Portland cement—the product patented by

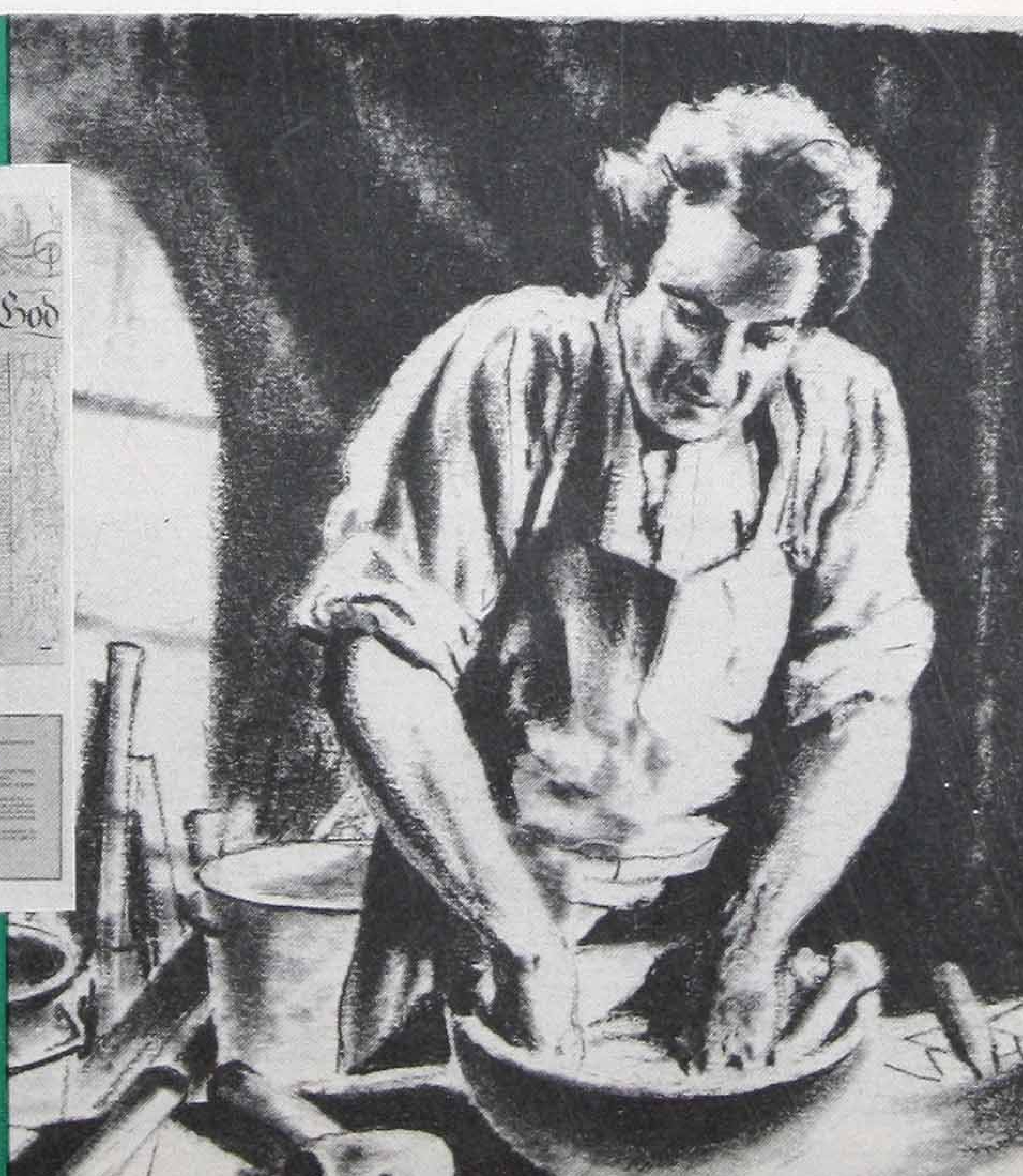
Aspdin—is a predetermined and carefully proportioned chemical combination of lime, silica, iron oxide and alumina. Before portland cement was discovered and for some years after its discovery, large quantities of natural cement were used. Natural cement was produced by burning a naturally occurring mixture of lime and clay. Because the ingredients of natural cement were mixed by Nature, its properties varied as widely as the natural resources from which it was made. Thus natural cement gave way to portland cement, which is a predictable, known product of consistently high quality. Today, about 98 per cent of the cement produced in the United States is portland cement.

In Aspdin's day, however, this new product caught on slowly. Aspdin established a plant in Wakefield to manufacture portland cement, some of which was used in 1828 in the construction of the Thames River Tunnel. But it was almost 20 years later—when J. D. White and Sons set up a factory in Kent which prospered—that the portland cement industry saw its greatest period of early expansion, not only in England but also in Belgium and Germany. Portland cement was used for the construction of the London sewer system built in 1859–1867.

The first record of portland cement's being shipped to the United States was in 1868, when European manufacturers began using cement as ballast in tramp steamers, which enabled them to ship it at very low freight rates. The volume increased to a peak of nearly 3 million bbl. in 1895. After that date, Americans began producing increasing amounts of portland cement for themselves.

Left—The original patent on portland cement, shown here in a photographic reproduction, was granted in 1824 to Joseph Aspdin of Leeds, England, by King George IV. *Right*—Artist's conception of Joseph Aspdin depicts the father of portland cement in his workshop laboratory mixing powdered limestone and clay for burning in his home kiln.





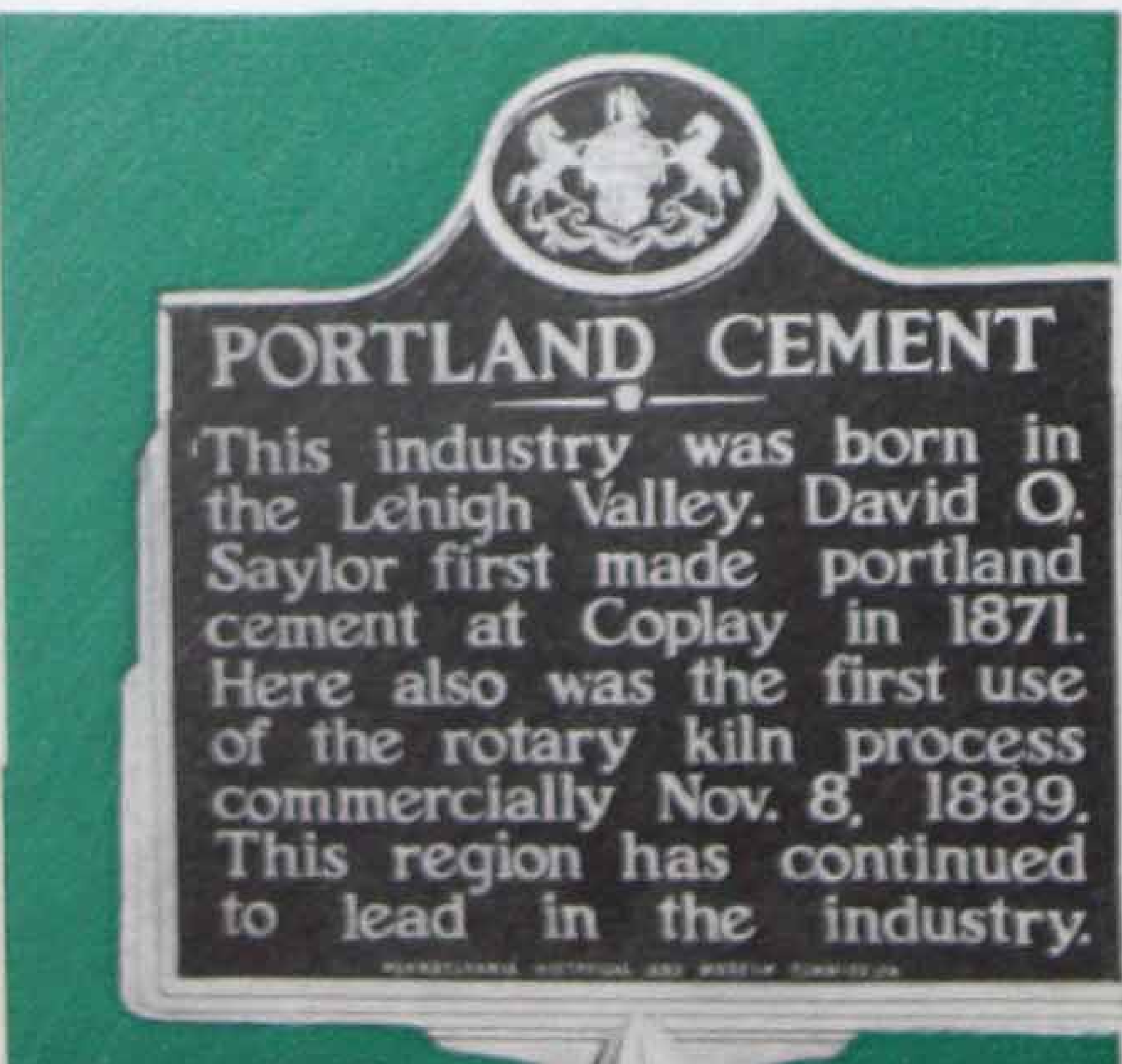
history and development of portland cement in the United States

CONSTRUCTION of a system of canals in the early nineteenth century created the first large-scale demand for cement in this country. In 1818, a year after the Erie Canal was started, an engineer named Canvass White discovered rock deposits in Madison County, N.Y., from which natural hydraulic cement could be made with little additional processing. He sold large amounts of this cement for use in the Erie Canal. Other deposits were found, principally in the Rosendale district of New York, the Louisville district of Indiana and Kentucky, and the Lehigh Valley of Pennsylvania. By 1899, nearly 10 million bbl. of natural cement was being produced annually in the United States and Canada.

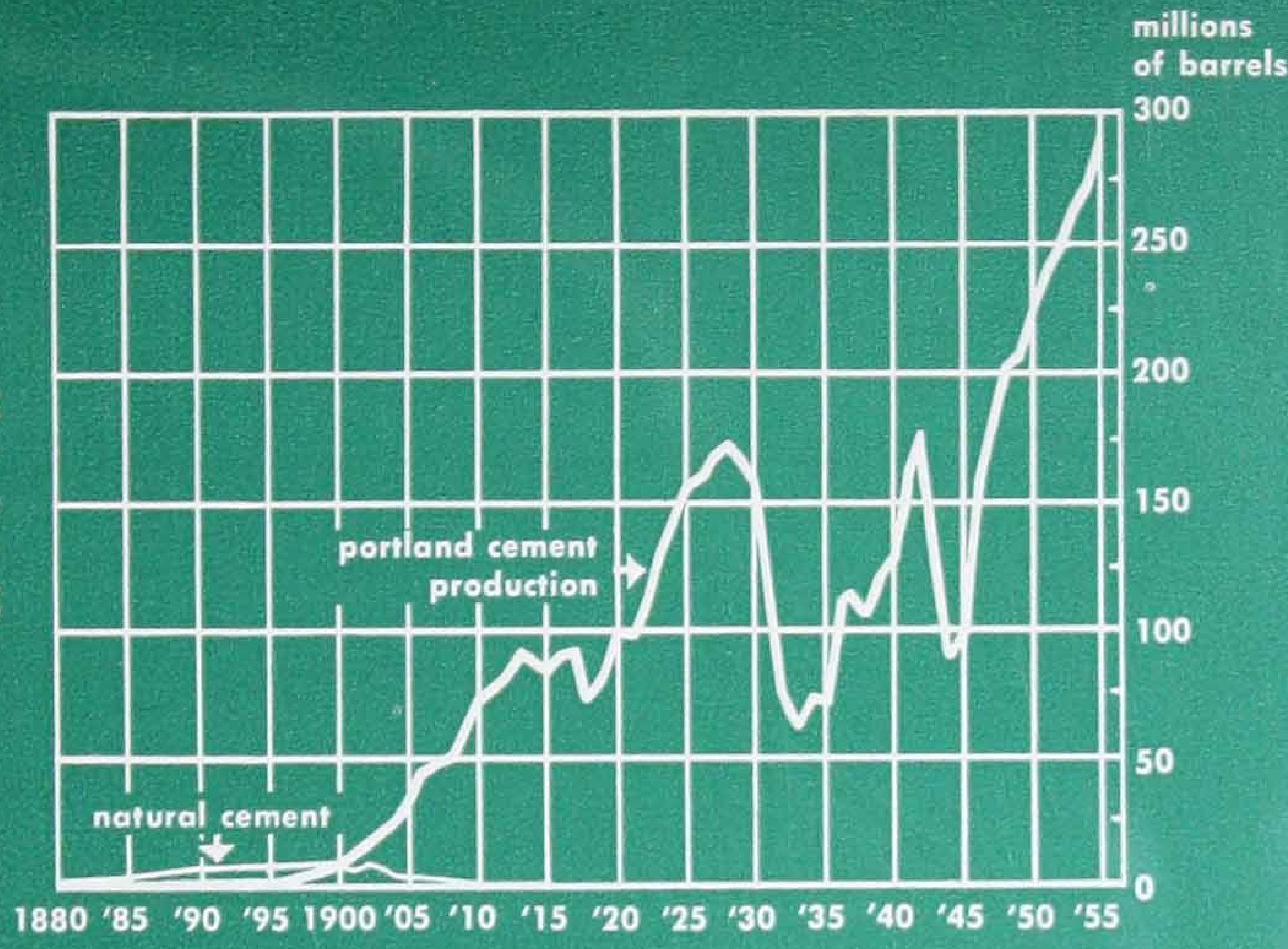
Although portland cement had been gaining in popularity in Europe since 1850, it was not manufactured in the United States until the 1870's. Probably the first plant to start production was that of David O. Saylor at Coplay, Pa. In 1871 Saylor tried his hand at selecting and mixing different kinds of rock from his quarries to produce portland cement. After initial difficulties he succeeded, and at the Centennial Exhibition in Philadelphia in 1876, samples of Saylor's product and that made by John K. Shinn at Wampum, Pa., compared favorably with the best imported portland cements.

While Saylor was perfecting his product in Pennsylvania, a firm in South Bend, Ind.—Thomas Millen and his two sons—was also experimenting with the

Left—This roadside plaque was erected by the Pennsylvania Historical Society in the Lehigh Valley, a great cement-producing region and birthplace of the portland cement industry in the United States. *Right*—The first portland cement produced in the United States was made in 1871 at the plant of David O. Saylor in Coplay, Pa. These vertical kilns, constructed at the Saylor plant about 10 years later, are still standing.



growth of the cement industry in the United States



manufacture of portland cement. Their first portland cement was burned in a piece of sewer pipe (perhaps the first experimental rotary kiln used in America), and the resulting clinker was ground in a coffee mill.

A notable pioneer in the industry in America was Robert W. Lesley. In 1874 he founded the firm of Lesley & Trinkle, cement brokers, dealing in both natural and portland cements. This led to his embarking in the manufacturing business for himself in Egypt, Pa. From his previous sales contacts, he picked up some ideas for time- and labor-saving devices for manufacturing portland cement, most notable of which was a method for pressing the pulverized raw materials into "eggettes" for burning in the kiln.

Rotary Kilns

In 1880, about 42,000 bbl. of portland cement was produced in the United States; a decade later the amount had increased to 335,500 bbl.; and since that time production has increased steadily until today the United States manufactures and uses more than two and one-half times as much portland cement as any other country in the world.

One factor in this tremendous increase was the development of the rotary kiln. In the early days, vertical stationary kilns were used and allowed to cool after each burning, with a resulting waste of fuel and time. In 1885 an English engineer, F. Ransome, patented a horizontal kiln, slightly tilted, which could be rotated so that the material moved gradually from one end to the other. Because this new type of kiln had much greater capacity and burned more thoroughly and uniformly, it rapidly displaced the older type. Thomas Edison was a pioneer in the further development of the rotary kiln. In his Edison Portland Cement Works in 1902, he introduced the first long kilns used in the industry—150 ft. in length in contrast to the customary 60 to 80 ft. Some kilns are 500 ft. and more in length. Parallel improvements in crushing and grinding equipment also influenced the rapid increase in production. (For annual production figures, see pages 12 and 13.)

the portland cement industry in continental United States, 1870–1955

source: Bureau of Mines, U. S. Department of the Interior

year	no. of active plants(a)	production, bbl.	value of product: total(b	averag net mi per bb
1870-1879		82,000	$ 246,000	$3.00
1880		42,000	126,000	3.00
1890	16	335,500	704,050	2.09
1895	22	990,324	1,586,830	1.60
1900	50	8,482,020	9,280,525	1.09
1901	56	12,711,225	12,532,360	0.99
1902	65	17,230,644	20,864,078	1.21
1903	78	22,342,973	27,713,319	1.24
1904	83	26,505,881	23,355,119	0.88
1905	89	35,246,812	33,245,867	0.96
1906	84	46,463,424	52,466,186	1.13
1907	94	48,785,390	53,992,551	1.11
1908	98	51,072,612	43,547,679	0.85
1909	108	64,991,431	52,858,354	0.81
1910	111	76,549,951	68,205,800	0.89
1911	116	78,528,637	66,248,817	0.84
1912	116	82,438,096	67,016,928	0.81
1913	113	92,097,131	92,557,617	1.01
1914	111	88,230,170	81,789,368	0.93
1915	109	85,914,907	73,886,820	0.86
1916	113	91,521,198	100,947,881	1.10
1917	118	92,814,202	125,670,430	1.35
1918	115	71,081,663	113,730,661	1.60
1919	111	80,777,935	138,130,269	1.71
1920	117	100,023,245	202,046,955	2.02
1921	115	98,842,049	186,811,473	1.89
1922	118	114,789,984	202,030,372	1.76
1923	126	137,460,238	261,174,452	1.90
1924	132	149,358,109	270,338,177	1.81
1925	138	161,658,901	286,136,255	1.77
1926	140	164,530,170	281,346,591	1.71
1927	153	173,206,513	280,594,551	1.62
1928	156	176,298,846	276,789,188	1.57
1929	163	170,646,036	252,556,133	1.48
1930	163	161,197,228	228,779,756	1.44
1931	160	125,429,071	140,959,906	1.11
1932	160	76,740,945	82,021,723	1.01
1933	152	63,473,189	85,600,717	1.33
1934	150	77,747,765	116,921,084	1.54
1935	150	76,741,570	113,372,182	1.51
1936	149	112,649,782	170,415,302	1.51
1937	150	116,174,708	168,835,208	1.48
1938	151	105,357,000	153,977,226	1.45
1939	149	121,934,911	180,321,811	1.47
1940	151	129,830,687	189,448,192	1.46
1941	154	163,567,931	245,616,442	1.47
1942	153	182,114,486	281,720,953	1.52
1943	151	132,445,838	197,812,259	1.56
1944	149	89,883,262	148,132,093	1.59
1945	142	101,340,500	170,317,436	1.62
1946	150	162,296,274	288,451,136	1.72
1947	148	184,644,179	350,874,595	1.89
1948	148	203,007,875	438,731,046	2.17
1949	148	207,535,473	467,067,991	2.29
1950	148	222,807,500	527,021,937	2.35
1951	153	241,782,416	601,918,133	2.54
1952	154	245,167,955	627,994,334	2.54
1953	154	260,524,908	687,927,387	2.67
1954	155	267,675,000	727,500,000	2.76
1955	155	292,634,000	791,418,000	2.86

(a) All *existing* plants prior to and including 1905.
(b) Value of product *produced* through 1929, value of product *shipped* after 1929.
(c) 1870–1880.
(d) 1900–1913 figures are estimates of cement used.
(e) Barrels of 376 lb. since 1920, and 380 lb. in earlier years.
(f) Imports in 1878 and 1879 only.
(g) Exclusive of U.S. possessions.
(h) Includes lime.
(i) Population estimates from Bureau of Census.

hipments from nills, bbl.	stocks on hand at end of year, bbl.	shipments within U.S., bbl. (d)	imports of hydraulic cement, bbl. (e)	exports of hydraulic cement, bbl. (g)	U.S. per capita use, bbl. (i)	year
———	———	———	198,000(f)	507,077(h)	—	1870-1879
———	———	———	187,000	41,989(h)	—	1880
———	———	———	1,940,186	86,963(h)	—	1890
———	———	———	2,997,395	83,682	—	1895
———	———	10,728,764	2,386,683	100,400	—	1900
———	———	13,216,026	939,330	373,934	—	1901
———	———	18,818,243	1,963,023	340,821	—	1902
———	———	24,309,479	2,251,969	285,463	—	1903
———	———	26,699,351	968,409	774,940	—	1904
———	———	35,245,971	896,845	897,686	—	1905
———	———	48,153,618	2,273,493	583,299	—	1906
———	———	49,918,278	2,033,438	900,550	—	1907
———	———	51,068,505	842,121	846,528	—	1908
———	———	64,378,397	443,888	1,056,922	—	1909
———	———	74,380,857	306,863	2,475,957	—	1910
5,547,829	10,385,789	72,577,090	164,670	3,135,409	—	1911
35,012,556	7,811,329	80,865,527	68,503	4,215,532	—	1912
38,689,377	11,220,328	85,809,649	85,470	2,964,358	—	1913
36,437,956	12,773,463	83,885,300	120,906	2,140,197	0.84	1914
36,891,681	11,462,523	84,230,966	42,218	2,565,031	0.83	1915
4,552,296	8,360,552	91,679,803	1,836	2,563,976	0.89	1916
0,703,474	10,353,838	87,765,565	2,323	2,586,215	0.84	1917
0,915,508	10,451,044	68,482,281	305	2,252,446	0.64	1918
35,612,899	5,256,900	82,465,381	8,931	2,463,573	0.77	1919
96,311,719	8,833,067	93,548,476	524,604	2,985,807	0.87	1920
5,507,147	12,192,567	94,286,002	122,317	1,181,014	0.87	1921
17,701,216	9,352,250	116,306,997	355,931	1,127,845	1.06	1922
35,912,118	10,812,639	134,703,313	1,767,264	1,001,688	1.21	1923
46,047,549	14,151,695	145,061,545	2,023,663	878,543	1.29	1924
57,295,212	18,336,173	156,117,674	3,667,548	1,019,597	1.38	1925
52,187,090	20,740,187	160,939,707	3,244,223	974,326	1.37	1926
71,864,728	22,457,382	170,736,616	2,065,730	816,726	1.44	1927
75,838,332	22,760,103	174,680,726	2,302,475	824,656	1.46	1928
69,868,322	23,700,533	168,754,196	1,745,345	885,321	1.41	1929
59,059,334	25,898,622	158,029,775	984,807	755,778	1.29	1930
27,150,534	24,342,446	126,404,657	469,598	429,653	1.02	1931
80,843,187	20,351,058	80,183,671	468,139	374,581	0.64	1932
64,282,756	19,605,323	63,305,426	477,193	680,307	0.50	1933
75,901,279	21,440,594	74,872,466	265,997	566,171	0.59	1934
75,232,917	23,064,563	74,320,911	619,404	416,099	0.58	1935
12,849,979	22,568,685	111,966,799	1,658,902	334,673	0.87	1936
13,804,782	24,913,245	112,782,328	1,803,932	378,554	0.87	1937
06,324,127	23,992,939	105,455,183	1,727,411	558,226	0.81	1938
22,303,478	23,644,333	121,339,558	1,913,853	1,146,339	0.95	1939
29,965,544	23,361,825	126,501,935	538,060	1,667,595	0.96	1940
66,974,079	19,964,616	160,335,730	43,466	2,556,234	1.25	1941
84,671,526	17,342,630	177,385,438	644	1,100,826	1.38	1942
26,649,772	23,155,469	120,658,095	13,658	1,731,956	0.95	1943
93,281,192	19,886,797	87,308,579	169	4,040,405	0.70	1944
04,856,406	16,421,666	96,457,004	323	6,474,721	0.77	1945
67,818,039	10,918,287	163,093,661	3,734	5,163,362	1.16	1946
85,587,744	9,989,096	179,253,344	4,606	6,771,250	1.25	1947
01,864,207	11,071,246	196,193,667	282,752	5,922,163	1.34	1948
03,908,839	14,715,597	200,248,023	109,821	4,561,899	1.35	1949
24,569,185	13,045,067	222,608,378	1,490,974	2,418,435	1.47	1950
36,855,689	18,048,145	235,047,389	921,953	2,932,787	1.53	1951
47,374,020	15,822,149	245,176,937	475,986	3,174,405	1.56	1952
57,237,400	19,109,657	255,263,471	386,051	2,535,549	1.65	1953
70,412,000	16,606,467	269,170,286	———	———	1.69	1954
88,579,000	17,411,000	287,191,000	———	———	1.74	1955

use of portland cement by states, 1955

sources: Bureau of Census[a]; Bureau of Mines[b]

state	population	shipments into states, bbl.	per capita use, bbl.	rank in per capita use	per cent of total used	rank in total used
Alabama	3,006,000	3,949,383	1.31	39	1.37	25
Arizona	955,000	2,336,869	2.45	9	0.81	33
Arkansas	1,770,000	2,519,045	1.42	37	0.88	30
California	12,696,000	31,553,460	2.49	7	10.99	1
Colorado	1,508,000	3,485,587	2.31	11	1.21	27
Connecticut	2,233,000	3,380,045	1.51	31	1.18	29
Delaware	380,000	1,096,849	2.89	2	0.38	42
Dist. of Columbia	831,000	1,395,480	1.68	27	0.49	38
Florida	3,364,000	8,996,778	2.67	3	3.13	9
Georgia	3,539,000	5,198,488	1.47	34	1.81	19
Idaho	606,000	922,657	1.52	30	0.32	45
Illinois	9,297,000	14,669,839	1.58	29	5.11	6
Indiana	4,325,000	8,072,919	1.87	22	2.81	10
Iowa	2,690,000	5,883,005	2.19	14	2.05	15
Kansas	2,021,000	7,248,402	2.19	15	2.52	13
Kentucky	2,948,000	3,636,286	1.23	40	1.27	26
Louisiana	2,902,000	7,346,885	2.53	6	2.56	12
Maine	890,000	961,477	1.08	43	0.33	43
Maryland	2,593,000	4,881,766	1.88	21	1.70	21
Massachusetts	4,972,000	5,238,608	1.07	44	1.82	18
Michigan	7,222,000	13,990,932	1.94	18	4.87	7
Minnesota	3,169,000	5,837,734	1.84	23	2.03	16
Mississippi	2,085,000	1,972,200	0.95	48	0.69	36
Missouri	4,094,000	7,824,142	1.91	20	2.73	11
Montana	628,000	950,537	1.51	32	0.33	44
Nebraska	1,369,000	3,484,902	2.55	5	1.21	28
Nevada	216,000	737,308	3.41	1	0.26	47
New Hampshire	553,000	1,147,139	2.07	16	0.40	41
New Jersey	5,370,000	9,337,446	1.74	26	3.25	8
New Mexico	769,000	1,996,330	2.60	4	0.70	35
New York	16,053,000	19,399,403	1.21	41	6.76	3
North Carolina	4,190,000	4,413,729	1.05	45	1.54	24
North Dakota	641,000	1,150,319	1.79	25	0.40	40
Ohio	8,946,000	17,319,534	1.94	19	6.03	4
Oklahoma	2,136,000	4,785,127	2.24	13	1.67	23
Oregon	1,664,000	2,397,990	1.44	35	0.84	32
Pennsylvania	11,132,000	16,076,934	1.44	36	5.60	5
Rhode Island	814,000	821,767	1.01	47	0.29	46
South Carolina	2,226,000	2,461,423	1.11	42	0.86	31
South Dakota	672,000	1,221,036	1.82	24	0.43	39
Tennessee	3,399,000	5,088,161	1.50	33	1.77	20
Texas	8,351,000	20,781,217	2.49	8	7.23	2
Utah	776,000	1,835,225	2.36	10	0.64	37
Vermont	377,000	293,809	0.78	49	0.10	49
Virginia	3,421,000	4,801,246	1.40	38	1.67	22
Washington	2,497,000	5,655,665	2.26	12	1.97	17
West Virginia	2,001,000	2,053,494	1.03	46	0.71	34
Wisconsin	3,691,000	5,976,599	1.62	28	2.08	14
Wyoming	295,000	578,060	1.96	17	0.20	48
totals	162,284,000	287,163,238[c]	1.80		100.00	

[a] *Current Population Reports*, Bureau of Census, U.S. Department of Commerce, January 20, 1956.

[b] *Mineral Industry Surveys*, Monthly Cement Report, Bureau of Mines, U.S. Department of the Interior, December 1955.

[c] Total does not include 28,290 bbl. shipped to unspecified destinations. Imported barrelage is not included in shipment figures.

portland cement industry in Canada

NATURAL cement was first produced in Canada between 1830 and 1840 by Ruggles Wright, who used limestone from the banks of the Ottawa River in his plant at Hull, Que. The firm he founded later marketed the first Canadian-produced portland cement in 1889, when the demand for this product virtually supplanted the demand for natural cement.

Another early Canadian cement manufacturer was Major-General Baddley, who made natural hydraulic cement from the black limestone of Quebec in 1856. Other early plants were located on the Gaspé Peninsula, in Argenteuil County, Que., and at Kingston and Thorold, Ont.

About 1887 imported portland cement began to appear in considerable quantities in Canada, and because of its superiority gradually replaced the domestic

production of portland cement in Canada 1900–1955

year	barrels	year	barrels
1900 . . .	417,552	1937 . . .	6,186,971
1910 . . .	4,753,975	1938 . . .	5,519,102
1920 . . .	6,651,980	1939 . . .	5,731,264
1921 . . .	5,752,885	1940 . . .	7,559,648
1922 . . .	6,943,972	1941 . . .	8,368,711
1923 . . .	7,543,589	1942 . . .	9,126,041
1924 . . .	7,498,624	1943 . . .	7,302,289
1925 . . .	8,116,597	1944 . . .	7,190,851
1926 . . .	8,707,021	1945 . . .	8,471,679
1927 . . .	10,065,865	1946 . . .	11,560,483
1928 . . .	11,023,928	1947 . . .	12,202,696
1929 . . .	12,284,081	1948 . . .	14,003,656
1930 . . .	11,032,538	1949 . . .	16,061,369
1931 . . .	10,161,658	1950 . . .	16,741,826
1932 . . .	4,498,721	1951 . . .	17,007,812
1933 . . .	3,007,432	1952 . . .	18,405,003
1934 . . .	3,783,226	1953 . . .	22,412,772
1935 . . .	3,648,086	1954 . . .	22,622,021
1936 . . .	4,508,718	1955 . . .	25,115,425

source: *Canadian Statistical Review,* Dominion Bureau of Statistics

natural cements. By 1889 consumption of portland cement in Canada had reached 122,273 bbl., all of it imported.

In this year four plants—at Hull, Napanee, Shallow Lake (near Owen Sound), and Longue Pointe (near Montreal)—did pioneer work in manufacturing portland cement. In 1890, 102,216 bbl. of domestic portland cement was produced.

The years 1898 to 1905 saw a rapid expansion of portland cement plants in Canada. By the end of 1905, their producing capacity was 3½ million bbl. per year, with about 80 per cent of this capacity located in Ontario. About 1891 the Canadian Pacific Railway started large-scale replacement of wooden structures with concrete in the mountainous regions of western Canada. It employed a chemist to investigate mineral deposits in this area, with the result that a small cement plant was built near Vancouver. From this beginning, the industry expanded in British Columbia, Alberta and Manitoba.

Since the turn of the century, portland cement has played a large part in the growth of Canada.

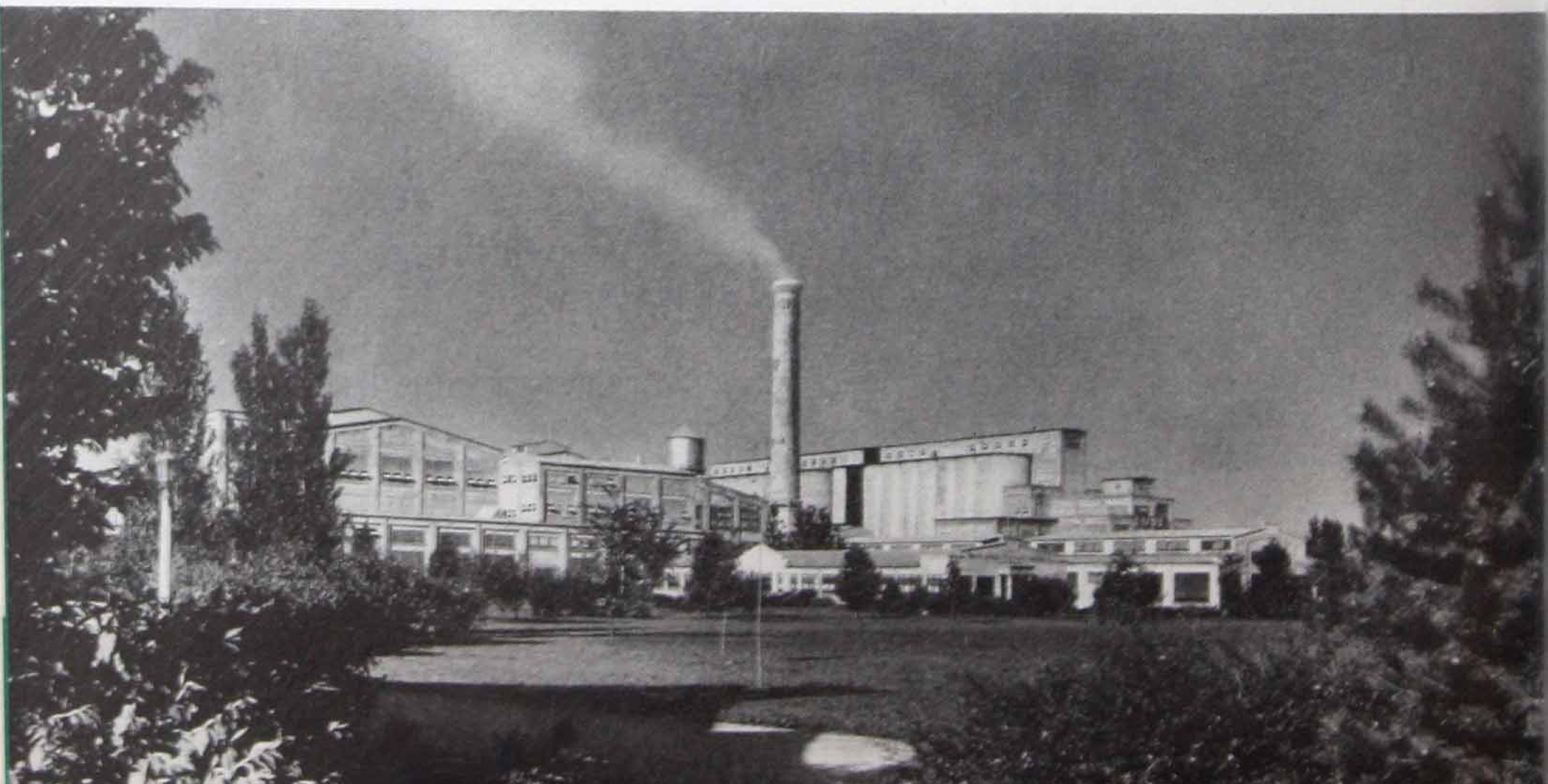
Today, Canada's twelve cement plants are situated in seven provinces—three in Ontario, four in Quebec, and one each in Alberta, Manitoba, British Columbia, Newfoundland and New Brunswick.

The 25,115,425 bbl. of cement shipped from these plants in 1955 represented an almost 300 per cent increase over shipments 10 years earlier. Rate of use of portland cement in the Dominion in 1955 was 1.61 bbl. per person.

Cement Products Industry

Along with the growth of the Canadian portland cement industry, there has been a comparable expansion of the concrete products industry in Canada. During the five-year period 1951–1955, Canadian concrete products manufacturers increased their annual output of concrete brick from more than 62 million units to more than 153 million, and their concrete block production from about 98 million units to more than 106 million. Canadian producers also turned out 510,000 tons of concrete pipe and tile in 1955.

A modern cement plant contains some of the largest pieces of moving machinery used in any industry. Modern rotary cement kilns are, in many instances, longer than a football field.



manufacture of portland cement

Joseph Aspdin, bricklayer of Leeds, England, who first made portland cement early in the nineteenth century by burning powdered limestone and clay in his kitchen stove, probably never considered his experiments in the light of putting a mountain through a sieve. But he laid the foundation for the portland cement industry of today, which every year processes literally mountains of limestone, clay, cement rock and other raw materials into a powder so fine it will pass through a sieve capable of holding water.

Portland cement, the basic ingredient of concrete, is a closely controlled chemical combination of lime, silica, alumina, iron oxide and small amounts of other ingredients—to which gypsum is added in the final grinding process to regulate the setting time of the concrete. Lime and silica make up approximately 85 per cent of the mass. Common among the materials used in its manufacture are limestone, shells and chalk or marl, combined with shale, clay, slate or blast-furnace slag, silica sand and iron ore.

The exacting nature of portland cement manufacture (see page 56) requires some 80 separate and continuous operations, the use of a great deal of heavy machinery and equipment, and large amounts of heat and electrical energy. Consequently, the capital investment per worker in the cement industry is among the highest in all industries.

Each step in the manufacture of portland cement is checked by frequent chemical and physical tests in plant laboratories. The finished product is also analyzed and tested to insure that it complies with the exacting applicable specifications of the American Society for Testing Materials, the Federal Specifications Executive Committee or other specifying agencies.

Two Processes Used

Two different processes are used in the manufacture of portland cement. One is the dry process; the other, the wet.

When rock is used as the principal raw material, the first step in both processes after quarrying is the primary crushing. Mountains of rock are fed through crushers capable of handling pieces as large as an oil drum. The first crushing reduces the rock to a top size of about 6 in. The rock then goes to secondary crushers or hammer mills for reduction to approximately 2-in. size or smaller.

In the wet process, the raw materials, properly proportioned, are then ground with water, intimately mixed and fed into the kiln in the form of a "slurry" (containing enough water to make it of a fluid consistency). In the dry process, raw

materials are ground, mixed and fed to the kiln in a dry state. Otherwise, the two processes are essentially alike.

New Product Formed

The raw material is then raised to a temperature of approximately 2,700 deg. F. in huge cylindrical steel rotary kilns lined with special firebrick. Kilns are frequently as much as 12 ft. in diameter—large enough to accommodate an automobile and longer in many instances than the height of a 40-story building. Kilns are mounted with the axis inclined slightly from the horizontal. The finely ground raw material or the slurry is fed into the higher end. At the lower end is a roaring blast of flame, produced by precisely controlled burning of powdered coal, oil or gas under forced draft.

As the material moves through the kiln, certain combinations of elements are driven off in the form of gases. The remaining elements unite to form a new substance with its own physical and chemical characteristics. The new substance, called "clinker," is formed in pieces about the size of marbles.

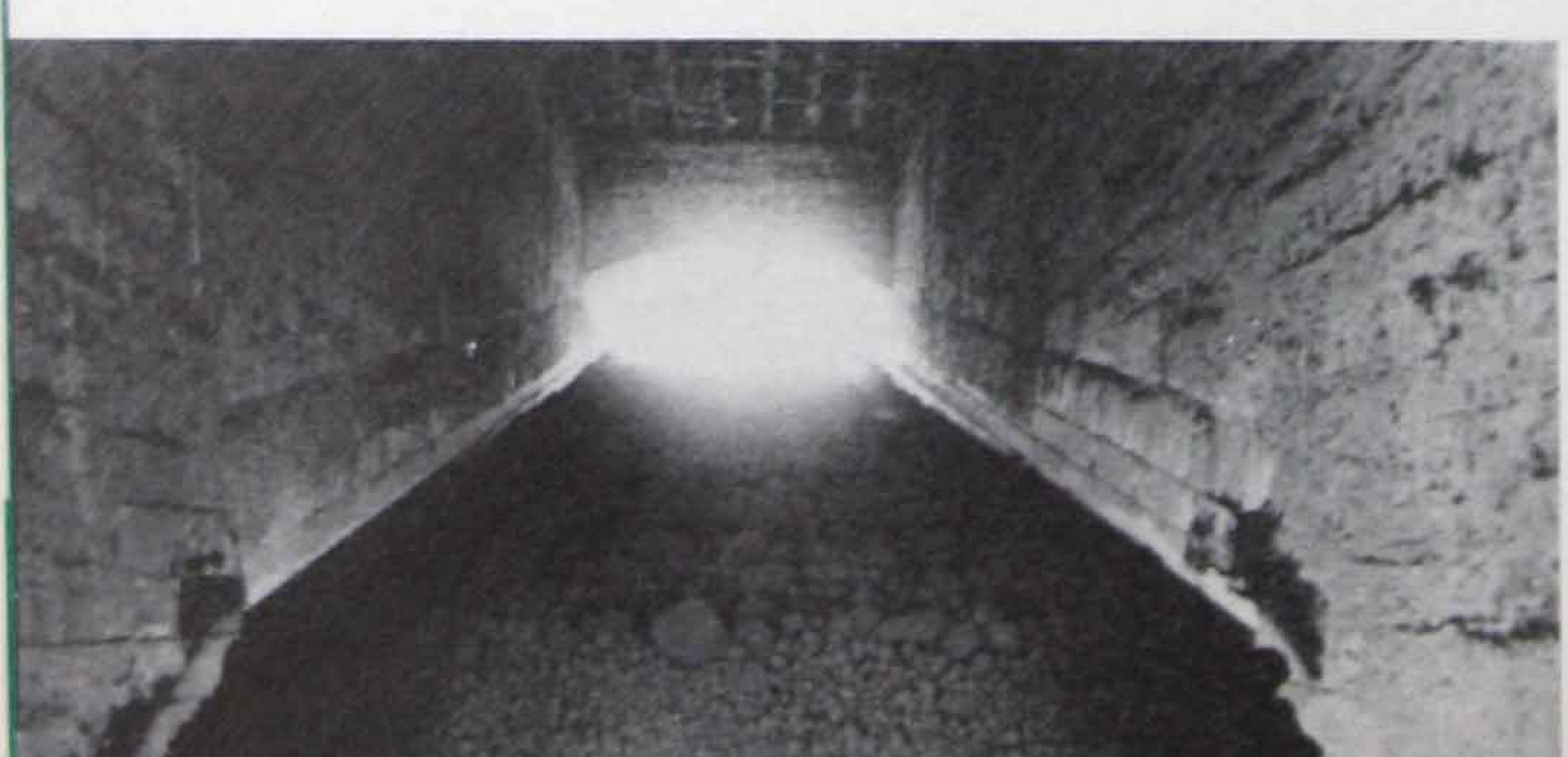
Clinker is discharged red-hot from the lower end of the kiln and is generally brought down to handling temperature in various types of coolers. The heated air from the coolers is returned to the kilns, a process that saves fuel and increases burning efficiency.

Final Grinding Completes Cycle

The clinker may be stockpiled for future use, or it may be conveyed immediately to a series of grinding machines. Here gypsum is added and the cycle from "mountain to sieve" is completed. The final grinding operation reduces the clinker to a powder called portland cement, a powder so finely ground that more than 90 per cent of it will pass through a screen containing 40,000 openings to the square inch; more than 80 per cent will pass through a screen that has 100,000 openings to the square inch.

Strong paper sacks, which are sealed before receiving the cement, are then filled through a small opening or "valve" from a packing machine that automatically cuts off the flow of cement when 94 lb. has entered the sack. When cement is shipped in bulk, it is pumped into hopper-bottom railroad cars, trucks, barges or ships and is accurately weighed.

Production and shipment figures on portland cement (see pages 12 and 13) are compiled by the U.S. Bureau of Mines, which uses barrels containing cement weighing 376 lb. net as units of measure, even though it has been many years since any American cement, except for export, was shipped in barrels. The 94-lb. bag now in general use contains one-fourth of a "barrel" or 1 cu.ft.



Cement "clinker," burned in a kiln at temperatures as high as 2,700 deg. F., passes through a cooler before going to storage.

materials used in portland cement manufacture

source: Bureau of Mines, U.S. Department of the Interior

In 1953—the latest year for which data on raw materials are available—the Bureau of Mines reported that approximately 84,937,000 tons of raw materials (exclusive of fuels and explosives) entered into the manufacture of 260,524,908 bbl. of portland cement in the United States. This is an average of about 643 lb. of raw materials for each barrel of finished portland cement weighing 376 lb. Loss of weight is caused by the process of calcination, in which moisture, carbon dioxide and other gases are driven off in the kilns. Materials are chiefly high-calcium limestone, clay or shale, argillaceous limestone, blast-furnace slag and marl. Totals were:

	short tons
cement rock	14,579,919
limestone and oyster-shells	55,619,940
marl	1,291,726
clay and shale	8,606,483
blast-furnace slag	1,408,486
gypsum	1,956,093
sand and sandstone	888,359
iron materials	410,420
other materials such as diatomite, fluorspar, pumicite, flue dust, pitch, red mud and rock, hydrated lime, tufa, cinders, calcium chloride, sludge, grinding acids, and air-entraining compounds	176,173
total	84,937,599

fuels consumed by the portland cement industry[a]

The following quantities of fuel were used by the portland cement industry in 1954 in the manufacture of 271,277,000 bbl. of portland cement in the United States and its territories:[b]

coal	8,158,784 tons
oil	276,521,238 gal.
gas	126,015,150 cu.ft.

Based on 1952 figures of cement production and fuel consumption in those plants that use one fuel exclusively, the following amounts of fuel were required to produce one barrel of cement:[c]

coal	112.9 lb.
oil	8.55 gal.
natural gas	1,405 cu.ft.

(a) Figures are for all cement-mill fuel consumption—including the process of burning in the kilns, independent power production and other uses.

(b) *Mineral Industry Surveys*, Monthly Cement Report No. CP 403, Bureau of Mines, U.S. Department of the Interior, 1954.

(c) *Mineral Industry Surveys*, Mineral Market Report No. MMS 2232, Bureau of Mines, U.S. Department of the Interior, 1952.

Storage bins are filled and emptied by a traveling crane with clamshell bucket that operates the length and width of the area. Clinker, gypsum, crushed limestone and other materials are stored here.

world cement production, 1953 — all types of hydraulic cements — source: Bureau of Mines, U. S. Department of the Interior

	country[a]	production in barrels[b]	country[a]	production in barrels[b]
North America	Canada	22,577,000	Mexico	9,803,000
	Cuba	2,385,000	Nicaragua	141,000
	Dominican Republic	752,000	Panama	469,000
	Guatemala	393,000	Salvador	212,000
	Jamaica	586,000[c]	United States	267,665,000[d]
South America	Argentina	9,639,000	Ecuador	534,000
	Bolivia	199,000	Paraguay	18,000
	Brazil	11,967,000	Peru	2,633,000
	Chile	4,468,000	Uruguay	1,741,000
	Colombia	5,119,000	Venezuela	5,758,000
Europe	Austria	8,173,000	Luxembourg	862,000
	Belgium	27,124,000	Netherlands	5,048,000
	Bulgaria	3,811,000[c]	Norway	4,492,000
	Czechoslovakia	15,362,000[c]	Poland	19,466,000
	Denmark	7,388,000	Portugal	4,509,000
	Finland	5,494,000	Rumania	12,313,000
	France	53,063,000	Spain	19,091,000
	Saar	1,788,000	Sweden	13,579,000
	East Germany	13,486,000[c]	Switzerland	9,276,000
	West Germany	90,160,000	U.S.S.R.	93,813,000[c]
	Greece	4,116,000	United Kingdom	66,824,000
	Hungary	6,450,000[c]	Yugoslavia	7,511,000
	Italy	44,291,000		
Asia	Burma	240,000	Japan	51,409,000
	Ceylon	377,000	Korea, Rep. of	258,000
	China	13,486,000[c]	Lebanon	1,788,000
	Hong Kong	377,000	Malaya	152,000
	India	22,514,000	Pakistan	3,553,000
	Indo-China	1,706,000	Philippines, Rep. of	1,740,000
	Indonesia	868,000	Syria	1,313,000
	Iran	410,000	Taiwan (Formosa)	3,049,000
	Iraq	1,038,000	Thailand	1,689,000
	Israel	2,726,000	Turkey	3,108,000
Africa	Algeria	2,870,000	French Morocco	3,577,000
	Angola	170,000	French West Africa	352,000
	Belgian Congo	1,636,000[c]	North Rhodesia	410,000[c]
	Egypt	6,432,000	Tunisia	1,331,000
	Ethiopia	59,000[c]	Union of So. Africa	13,454,000
Oceania	Australia	9,372,000	New Zealand	1,642,000
	total	1,028,283,000[e]		

[a] Converted to barrels from metric tons (1 bbl. = 376 lb.).
[b] In addition to countries listed, hydraulic cement is produced in Albania and Eritrea, but production is believed to be negligible.
[c] Estimated.
[d] For production of portland cement in the United States see table on page 12.
[e] Data not available for Ireland, Madagascar, Mozambique, North Korea and Southern Rhodesia; estimate is included in total.

what it is and how it is made

CONCRETE is a mixture in which a paste of portland cement and water binds aggregates (inert materials such as sand and gravel, crushed stone, blast-furnace slag) into a rocklike mass as the paste hardens through the chemical action of the cement and water. A durable, strong concrete is obtained by correctly proportioning and properly mixing the ingredients so that the entire surface of every particle of aggregate from the smallest grain of sand to the largest piece of coarse material is completely coated with the cement paste, and so that the spaces between aggregate particles are completely filled with the paste.

Easily Molded

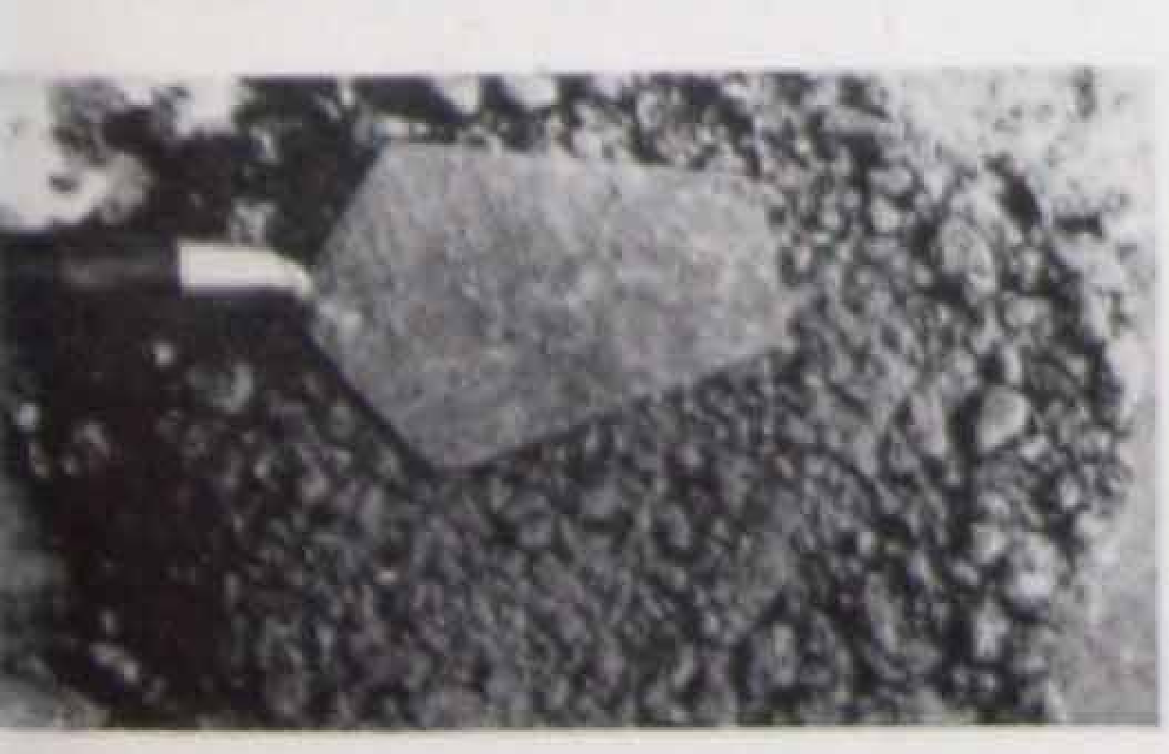
When first mixed, concrete is easily molded. At this stage it may be troweled to a smooth surface, brushed to obtain a rough texture, or shaped into ornamental patterns. It is often placed in specially made forms to reproduce elaborate ornamentation and intricate designs.

Proportioning of the ingredients of concrete is often referred to as "designing the mixture." A properly designed mix will achieve the characteristics desired in both the fresh and hardened concrete.

Water-Cement Ratio

The character of the concrete is determined in large measure by the quality of the cement-water paste that binds the aggregates together. If too much water is used, the paste becomes thin and diluted and when it hardens will be too weak to

Good concrete is obtained by correct proportioning of materials and proper mixing, placing and curing. Here are: (1) A concrete mixture in which there is not sufficient cement-sand mortar to fill all the spaces between coarse aggregate particles. Such a mixture will be difficult to handle and place and will result in rough, honeycombed surfaces and porous concrete. (2) A concrete mixture that contains the correct amount of cement-sand mortar. With light troweling all spaces between coarse aggregate particles are filled with mortar. (3) A concrete mixture in which there is an excess of cement-sand mortar. While such a mixture is workable and will produce smooth surfaces, the yield of concrete will be low and consequently uneconomical.



hold the aggregates firmly together. The strength of the cement paste and ultimately the durability, strength and other properties of the concrete depend on the amount of mixing water used. The relation of water to cement is usually referred to as the water-cement ratio. The higher this ratio, that is, the more water used per unit of cement, the less durable and strong will be the concrete. The lower this ratio, so long as the concrete is workable, the better will be the quality of the concrete.

Concrete can be made to have any desired degree of watertightness. It can be made to hold water or other liquids and resist the penetration of wind-driven rain. Yet for some special purposes, such as filter beds, concrete can be made porous and highly permeable.

Economy in a concrete mixture designed for durability, strength and watertightness is effected by using no more cement paste than is required to coat all the aggregate surfaces and fill all the voids.

Purpose Determines Mix

Concrete can be given a polished surface as hard as glass. By the use of heavy aggregates, dense concrete mixtures can be made that will weigh 250 lb. or more per cu.ft. With the use of light aggregates or special processes, it can also be made so light that it will float, and can be sawed or nailed like lumber—weighing as little as 30 lb. per cu.ft. The type of mixture used is determined by the purpose for which the concrete is intended.

For very small jobs and for minor repairs, concrete can be mixed by hand, but mixing concrete by machine insures more uniform batches as well as more thorough mixing of ingredients.

For most home repairs and improvements such as floors, walks, driveways, playcourts, garden pools, storage cellars or garden furniture, the following proportions of concrete materials are recommended: 1 bag (1 cu.ft.) of portland cement, 6 gal. of water, and such quantities of sand and gravel as will result in a workable mixture (usually 2 cu.ft. of dry sand and 3 cu.ft. of coarse aggregates). When properly mixed, these proportions will produce a watertight concrete that is highly resistant to weather and wear. If the sand is wet, add 5 gal. of mixing water for each bag of cement (instead of 6 gal.), since 2 cu.ft. of wet sand will contain approximately 1 gal. of water. Any water that is fit to drink is suitable to use for making concrete.

Aggregates

The aggregates should be clean, sound and free from vegetable matter. Commercial aggregates are usually suitable.

All sand (fine aggregate) should pass through a ¼-in. sieve (one with four openings to the inch). The size of coarse aggregates depends on the thickness of the member for which the concrete is to be used. In building garden pools, for example, or other structures with relatively thin sections, a small-diameter coarse aggregate would be used, while—at the other extreme—aggregates up to 6 in. or more in diameter are used in large dams. In general, the maximum diameter of coarse aggregate should not be larger than one-fifth of the narrowest dimension of the concrete member in which it is used.

Placing and Finishing

After the concrete is thoroughly mixed and of the desired workability, it should be placed in the forms within 1½ hours after mixing. It should be of proper workability at the time of placing and should be well compacted and spaded during the placing process.

On such jobs as floors, walks, steps and driveways, the concrete should be leveled off with a straight-edged board as soon as it is placed, and then allowed to stand until the film of moisture disappears from the surface. It should then be smoothed off quickly with a woodfloat. If a very smooth surface is desired, the concrete may be finished with a steel trowel after the woodfloat has been used. The woodfloat, however, produces a nonslippery surface highly desirable for walks, steps and driveways. A steel trowel should be used sparingly and only after the concrete has become quite stiff, in order to avoid bringing an excessive amount of fine particles to the surface.

After exposed surfaces of the concrete have hardened sufficiently to resist marring, they should be sprinkled with water and protected by moisture-retaining materials such as canvas, burlap or moist sand, to prevent their drying out. The longer concrete is kept moist, the more durable and stronger it will become. In hot weather it should be kept moist for not less than three days.

Ready-Mixed Concrete

Ready-mixed concrete is concrete produced by a manufacturer and delivered by truck to the construction site. The method of mixing may vary. It may be done at the manufacturer's plant, on the truck in transit, or at the job site.

Ready-mixed concrete became established as an important construction material soon after World War I and has grown steadily in popularity. According to estimates of the National Ready Mixed Concrete Association, there are approximately 2,000 ready-mixed concrete producers in the United States and Canada.

A Thousand Uses

Although most people recognize the more common uses of concrete around the home and for the paving of streets and highways, few realize the extent to which they are surrounded by and dependent on concrete.

It is interesting to note in a U.S. Bureau of Mines *Minerals Yearbook* this statement:

"Portland cement occupies a dominant position in modern civilization. . . . It is now regarded as indispensable in highways, sidewalks, bridges and dams; in the construction of virtually all large buildings; and in airport runways, dry docks, harbors and a multitude of other major and minor projects. Both farmers and city dwellers use it in innumerable ways."

Here is one of America's most popular machines in action. Concrete mixers like this one are mostly used for small projects and around-the-house jobs.

air-entrained concrete

AIR-ENTRAINED concrete—one of the newest developments in the cement and concrete industries—contains billions of microscopic air cells per cubic foot. These relieve internal pressure on the concrete by providing tiny chambers for the expansion of water when it freezes.

Air-entrained concrete is produced through the use of air-entraining portland cement—or by the introduction of air-entraining agents under careful engineering supervision as the concrete is mixed on the job. The amount of entrained air is usually between 3 and 6 per cent of the volume of the concrete, but may be varied from this as required by special conditions.

A direct result of many years of intensive research by the Portland Cement Association and others, air-entraining portland cement is made by grinding small amounts of soaplike resinous or fatty materials with normal cement clinker.

First Developed for Highways

The general practice of using calcium or sodium chlorides to melt ice on roads and streets created the necessity for a means of protecting concrete pavements from surface scaling caused by the action of these chemicals. Air-entraining portland cement was originally developed to prevent this scaling.

The use of air-entraining agents results in concrete that: (1) is highly resistant to severe frost action and cycles of wetting and drying or freezing and thawing; (2) has a high immunity to the surface scaling caused by excessive amounts of chemicals used to melt pavement ice; and (3) has a remarkably high degree of workability and durability.

The West Virginia Turnpike, shown below, is an example of air-entrainment construction, with sawed joints to provide a smoother ride for the motorist. Thirty-six state highway departments now specify air-entrained concrete for pavements.

For these reasons, the value of air-entrained concrete has become widely recognized in the past 10 years, not only for pavements but for other types of concrete construction.

Air-entrained concrete is currently being specified by 36 state highway departments for all pavements, and under some conditions, by 10 others. In addition, many of these same states specify its use in all bridges and structures. It is also specified for appropriate jobs by federal agencies.

A survey of the condition of 14 experimental highway sections in five northeastern states—with an average age of 12⅓ years—proved that concrete pavements made with air-entraining portland cement withstand severe exposure including frequent applications of ice-removing chemicals. All the experimental projects were on main state routes subject to heavy traffic. Although other slabs showed varying degrees of scaling, no scaling whatever occurred on the slabs made with air-entrained concrete.

do you know that . . .

A $4 million floating concrete drydock being completed by the U.S. Navy contains 145,800 cu.ft. of concrete, weighs 12,800 tons and will have a lifting capacity of 4,000 tons? It will be equipped with its own power system and will be capable of ocean trips.

The new auditorium at the Massachusetts Institute of Technology has a thin-shell concrete roof that in shape resembles a spherical triangle? The roof consists of two concrete shells separated by 2 in. of rigid insulation. It is supported at only three points, with a 160-ft. span between each point.

The tallest chimney in the world is that of a copper company at Sagazanoseki, Japan? Built of reinforced concrete, it is 570 ft. high, with an outside diameter at the base of approximately 42½ ft. and an inside diameter at the top of 26 ft. It has withstood earthquakes successfully.

Through use of lightweight aggregates such as expanded blast-furnace slag, expanded shale, and natural products like pumice, the weight of finished concrete floors, bridge decks, roofs and structural members can be reduced by as much as one-third?

These magnified pictures show an ordinary straight pin photographed on two different cross-section specimens of concrete. On the left is a specimen of air-entrained concrete showing air cells, which total billions in a cubic foot. On the right is a section of non-air-entrained concrete.

what it is and what it does

THE Portland Cement Association is a national, nonprofit, unincorporated organization to improve and extend the uses of portland cement and concrete. Established with its main offices in Chicago since 1916, the Association is supported by the voluntary financial contributions of its more than 70 member cement companies in the United States and Canada. These member companies, widely spread geographically and operating 152 separate plants, produce a very large proportion of all portland cement used in the United States and Canada.

The founders of the Association realized that in order for portland cement to merit and attain widespread use and public confidence, a vast amount of basic research, product development, technical service, education and promotion would be required. If each company were to have undertaken this task independently, a tremendous duplication of effort and expense would have resulted. The Portland Cement Association was therefore formed in the interest of economy and efficiency and to insure a coordinated and sustained attack on the many complex problems of research, development and expansion of markets.

The Association's work is classified under four principal divisions:

1. Scientific research in the field of portland cement and concrete.
2. Development of new and improved cement-using products and methods.
3. Promotion, educational work and technical service to extend the uses of portland cement and to improve concrete quality.
4. Accident prevention work to encourage safety in the plants of its member companies.

To carry out this program, the Association maintains a general headquarters staff and a field organization. The headquarters staff is made up of more than 200 scientists, engineers, architects and writers, some employed in the Association's General Office in downtown Chicago, others in the PCA's Research and Development Laboratories 16 miles northwest of Chicago, and still others in connection with a fellowship at the National Bureau of Standards in Washington, D.C. The field organization includes more than 350 engineers, architects and farm specialists working out of 32 district offices and serving cement users in 46 states, the District of Columbia, and British Columbia.

The general headquarters staff (which includes the Research and Development Division) and the field organization work as a team to accomplish the Association's objectives. General headquarters coordinates and gives direction to the

The manifold activities of the Portland Cement Association are directed from this all-concrete general headquarters building in Chicago. The Association maintains 32 district offices to serve cement users in 46 states, the District of Columbia and British Columbia.

program and develops the required scientific and technical information. The field organization uses this material in direct contacts with the public.

The Association is in no way engaged in the production, distribution, pricing or selling of portland cement. It does not speak for the cement industry on commercial matters, and it has nothing to do with trade practices. But through its own research findings, its cooperation with other research and technical organizations, its wide variety of technical literature, its advertising and the daily contact of its skilled engineering staff with the actual problems of the designer and builder, the Portland Cement Association has become recognized as:

1. Principal source of technical service to cement users.
2. Clearinghouse for a vast fund of reliable, up-to-date information on portland cement, the making of concrete, design procedures and construction methods.
3. Leader in research and development studies on cement and concrete.

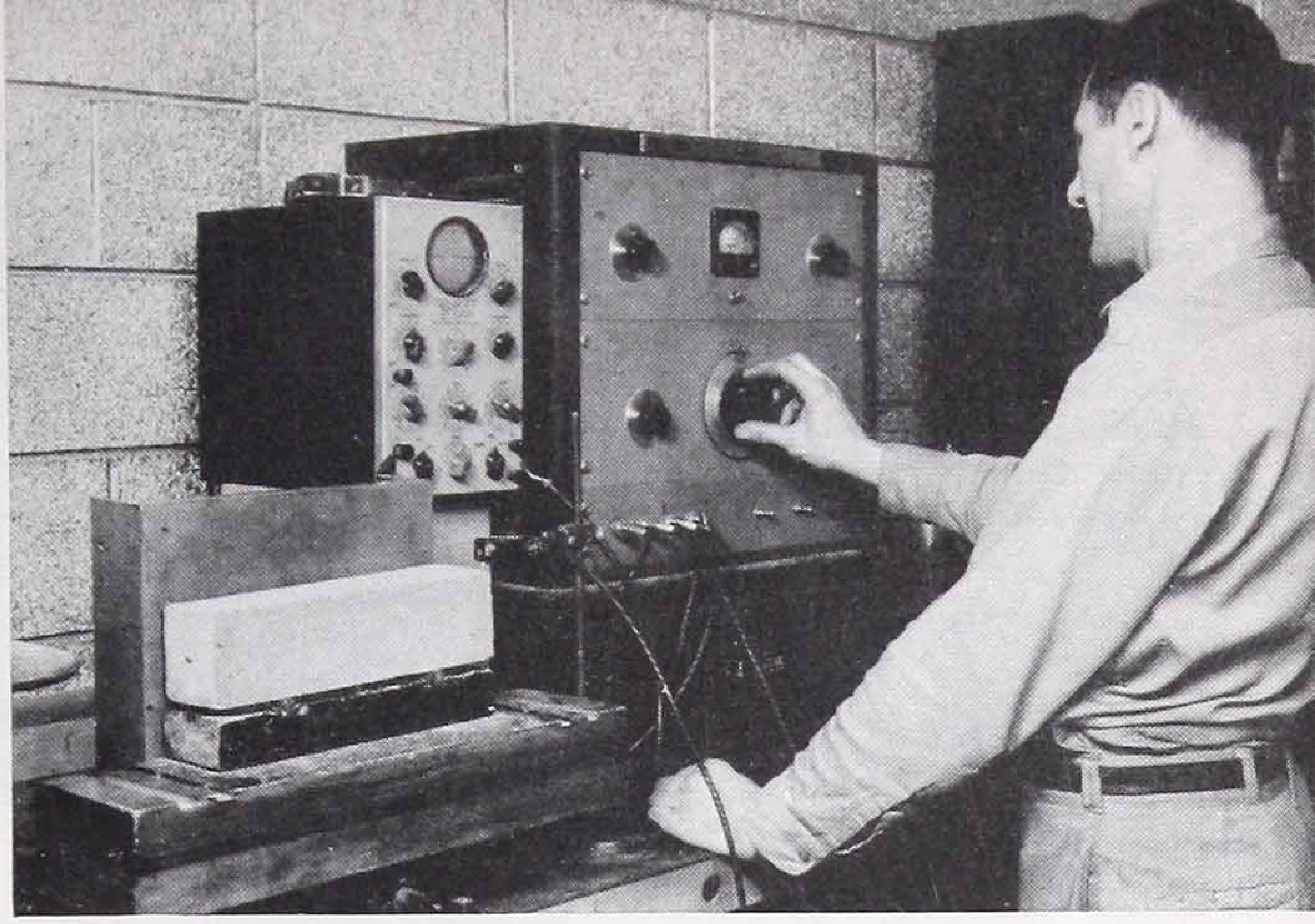
This record of cooperative research, development, education, service to the user, promotion of product and safety work is a source of pride and satisfaction to the cement companies whose support and membership in the Association have made these accomplishments possible.

cement and concrete research

WITHOUT a program of continuing scientific research in laboratory and field, many applications of portland cement and concrete, commonplace today, would be unknown or prohibitive in cost. America's network of concrete highways could not have been developed so rapidly but for painstaking research. The vast power and irrigation projects of today apply practical engineering principles that were untried theories half a century ago. Without the scientific developments and advances in concrete technology made possible by research, America today would have fewer soaring skyscrapers, modern factories or fire-safe schools, hospitals, apartment buildings and homes.

The people who direct the Portland Cement Association's research program recognize that establishing definite practices governing the use of cement insures reliable products, their proper application and the development of cement to its greatest usefulness. And in harmony with the broadest conception of public service, it is Association policy to make all scientific discoveries and new developments relating to cement and concrete fully, freely and immediately available to the public. All patentable inventions resulting from Association research and development work are given to the public gratis.

The Portland Cement Association's Research and Development Laboratories near Chicago are the largest and most completely equipped in the world devoted exclusively to research on cement and concrete.



By listening to concrete specimens "sing" on this high-frequency sonic testing machine, laboratory scientists gain important information for designing concrete to give maximum service for highways and countless other structures.

Research Findings Important

Since 1916, when the Portland Cement Association established research laboratories in Chicago, many important contributions have been made to concrete technology. Some of these developments have resulted in substantial savings in the cost of construction and greater durability and longer life for concrete structures.

The water-cement ratio principle of proportioning concrete mixtures was among the earliest and most far-reaching developments of Association research (see page 21). This established the fact of a definite relationship between the durability, strength and other properties of concrete and the amount of mixing water used per unit of cement measure. Another important contribution of cement industry research is the development of air-entraining portland cement to resist severe frost action and pavement scaling when certain chemicals are used to melt pavement ice (see page 24). Pressure-grouting to stabilize railway and highway subgrades and tunnels (see page 106), and soil-cement for low-cost light-traffic paving on roads, streets and airports (see page 61) are other important research developments.

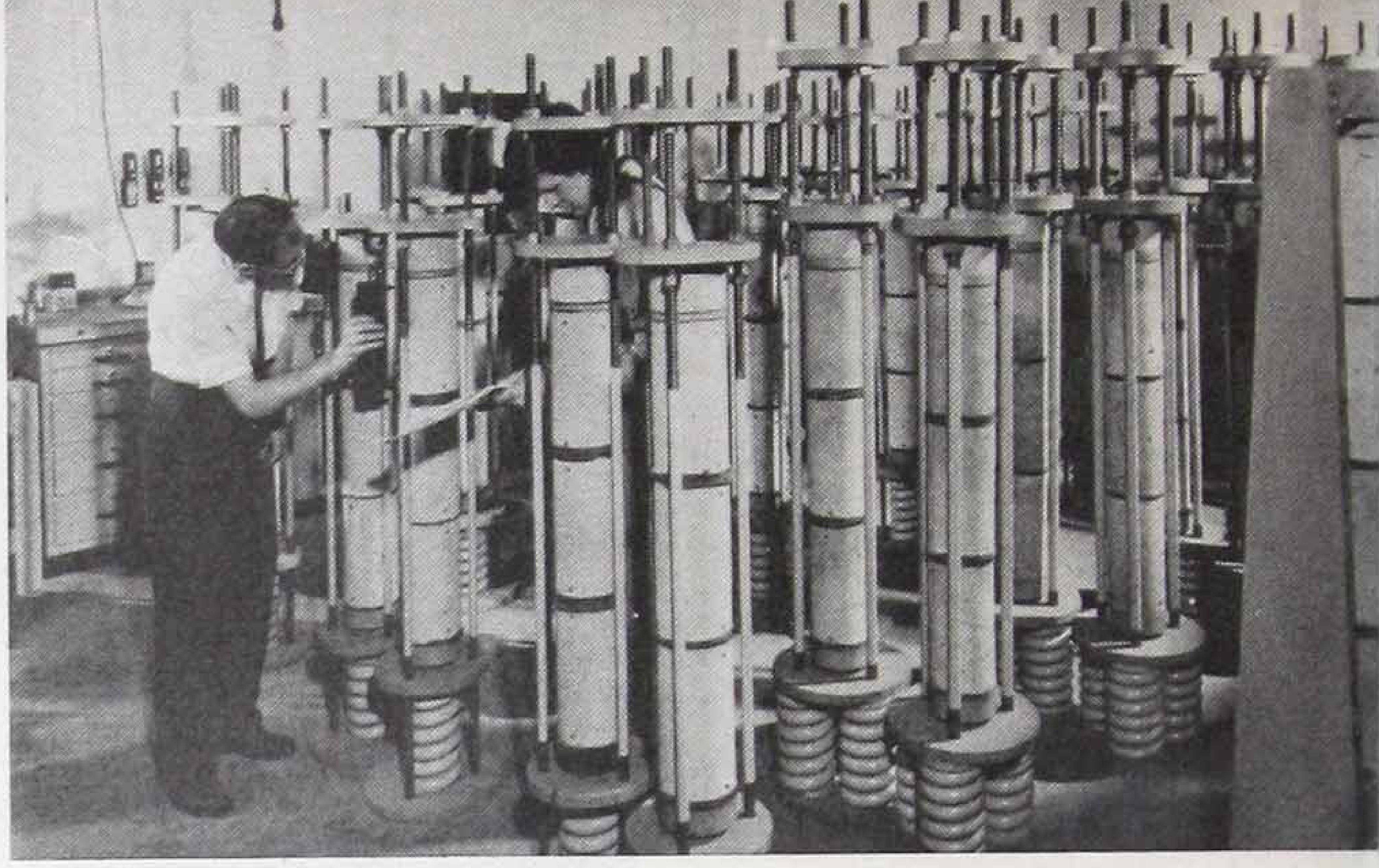
In addition to research conducted in the Association's large laboratories near Chicago, numerous field projects are in progress in many widely separated sections of the country—in low and high altitudes, in states with severe winter climate and in semitropical areas.

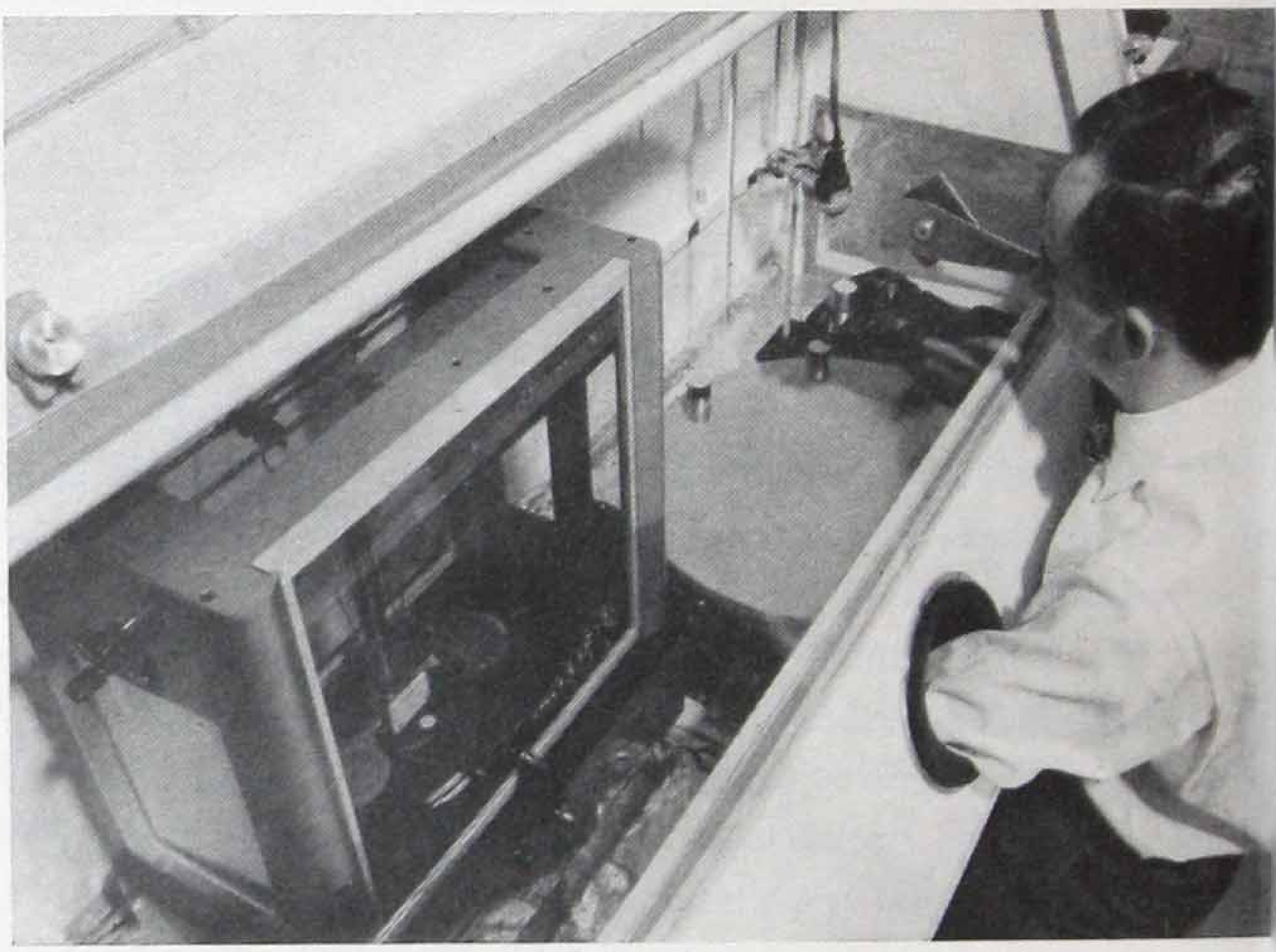
Long-Time Study Under Way

A far-reaching research project relating to portland cement is the long-time study of the performance of portland cement in concrete, started in 1940. This project is sponsored and financed by the Portland Cement Association, and conforms to a program prepared by an advisory committee made up of eight prominent research engineers and scientists outside the cement industry and four directly representing the industry. The basic purpose of the investigation is to determine what factors are responsible where differences in performance are found. More than 24,000 individual containers were required for the cement samples.

One phase of these studies was the building of two-lane concrete test pavements totaling more than six miles. Nearly 400 test sections were built with various materials used in rotation on different sections.

In this room of the Portland Cement Association laboratories, the relative humidity can be controlled between 10 and 80 per cent. Under controlled conditions, lightweight aggregate concrete columns are being tested for "creep" under sustained loads over an extended period of time.





A PCA physicist removes samples of cement paste from a revolving turntable in a controlled-atmosphere cabinet to a scale where minute variations in weight due to moisture evaporation are measured.

This small autoclave is used at the PCA laboratories to cure concrete masonry units under high steam pressure. Units are used for test purposes.

Other phases of the project included the casting and driving of large concrete piles into the waters of Cape Cod, the Hudson River, the Atlantic Ocean near St. Augustine, and the Pacific Ocean near Los Angeles; observation of the durability of a thousand concrete beams exposed to alkali soils near Sacramento, Calif.; testing of concrete at large dams in the high Sierra Nevada and the Rocky Mountains; and the establishment of two experimental test plots in Illinois and Georgia where some 2,000 concrete specimens are exposed to varying weather and soil conditions. All this involved the making of 9,000 laboratory specimens and 2,800 field specimens before the projects could get under way.

These far-flung studies are of direct and substantial benefit to the public. The findings will result in improving the durability and lengthening the service life of concrete structures under the various conditions of exposure.

Maintains Staff in Washington

In addition to sponsoring numerous laboratory and field research projects, the Association maintains a staff of research scientists at the National Bureau of Standards in Washington, D.C. They are working under a cooperative fellowship set up to study basic problems relating to the constitution and properties of portland cement.

A survey conducted by the American Concrete Institute Committee on Research has disclosed that engineering colleges and private and governmental agencies are engaged in more than 350 different research projects involving portland cement and concrete. The Portland Cement Association is actively cooperating in many of these projects in addition to its own research work. Included among the other agencies that are contributing much to cement and concrete technology are the U.S. Bureau of Reclamation, the National Bureau of Standards, the American Society for Testing Materials, engineering staffs of the Army, Navy and Air Force, the Public Roads Administration, and numerous state highway departments.

The Association's $3 million laboratories located 16 miles northwest of Chicago are the largest and most completely equipped in the world devoted exclusively to research on cement and concrete. Dedicated in 1950, they contain more than 98,000 sq.ft. of floor space and provide facilities for the research and development phases of the Association's manifold program of service.

One part of the Portland Cement Association's research program is a comparative long-time study of cement performance in concrete structures subjected to a variety of exposure conditions typical of those encountered in the United States.

educational program

THE job of the Portland Cement Association's educational program is to shorten the lag between the research laboratory and the actual field application of improved techniques in the use of cement and concrete. This program is of direct benefit to the public because it makes new developments and scientific discoveries in the field of cement and concrete immediately available to the people who will actually use them. Thus everyone benefits—from the contractor building a skyscraper and the home-owner installing a backyard barbecue pit, to the millions of people who drink water brought to them in a concrete pipe, live in firesafe concrete homes, drive on concrete highways over concrete bridges, work in concrete buildings, and in many other ways find concrete a vital part of their everyday lives.

Booklets Aid Cement Users

One of the most important educational activities of the Association is the preparation and distribution of a wide range of informative literature. The Association has available more than 400 individual publications covering the many fields in which cement and concrete are used.

Ranging from highly technical publications written for architects and engineers to simple, easily understandable information on how to build a septic tank, a basement wall or a sidewalk, single copies of these booklets are furnished free on individual requests originating in the United States and Canada.

Almost four and a half million pieces of Association literature are distributed in the average year. This figure includes technical reports and regular Association periodicals in addition to specially prepared booklets and information sheets. All publications are designed for the specific purpose of helping the users obtain the best possible service from portland cement.

Educational Advertising

The Association carries on a continuous program of educational advertising as an important means of keeping portland cement users informed on new developments in portland cement and concrete. National advertising appears in trade, professional, housing, farm and general consumer publications. Local advertising is placed through Association district offices in more than a thousand newspapers and local publications each year.

Lectures, Short Courses Offered

As a part of its educational program, the Association staff gives hundreds of lectures and demonstrations for engineers, construction superintendents and workers, farmers and others to help them get maximum service from concrete. It also provides educational information for engineering and architectural colleges, voca-

tional schools, farm organizations, technical groups and construction agencies, and assists with instruction on improved methods of concrete design and construction.

Another important phase of the educational program includes the Association's "short courses." In the last five years, more than 286,000 engineers, architects, contractors, producers of ready-mixed concrete, concrete products manufacturers and others have attended these courses to study how best to use portland cement, make quality concrete and soil-cement, and design and build concrete pavements and structures.

Association field representatives—active in 46 states, the District of Columbia and British Columbia—are in close touch with the storehouse of technical information compiled by the Association. By educating builders in the uses of cement, they help make it possible for the public to realize immediate benefits from new and improved construction practices. However, at no time does the Association staff furnish engineering or architectural plans, or in any way assume the functions of the engineer or architect.

Visual Aids Popular

The Association makes wide use of visual aids in its educational program. It has a number of slides and films, most of the latter in sound and color, to portray graphically the manufacture of portland cement and its use in many fields. These films are in constant demand by engineering and technical organizations, and by industrial, agricultural, business, social and educational groups.

The end result of the Association educational program is that thousands of engineers, architects, contractors and other users of cement are able—through intimate knowledge of latest developments—to effect immediate economies and improve the strength and durability of concrete structures to the ultimate benefit of every citizen of the country.

The two libraries of the PCA contain one of the most outstanding collections of technical material on cement and concrete to be found anywhere in the world.

safety record of the cement industry

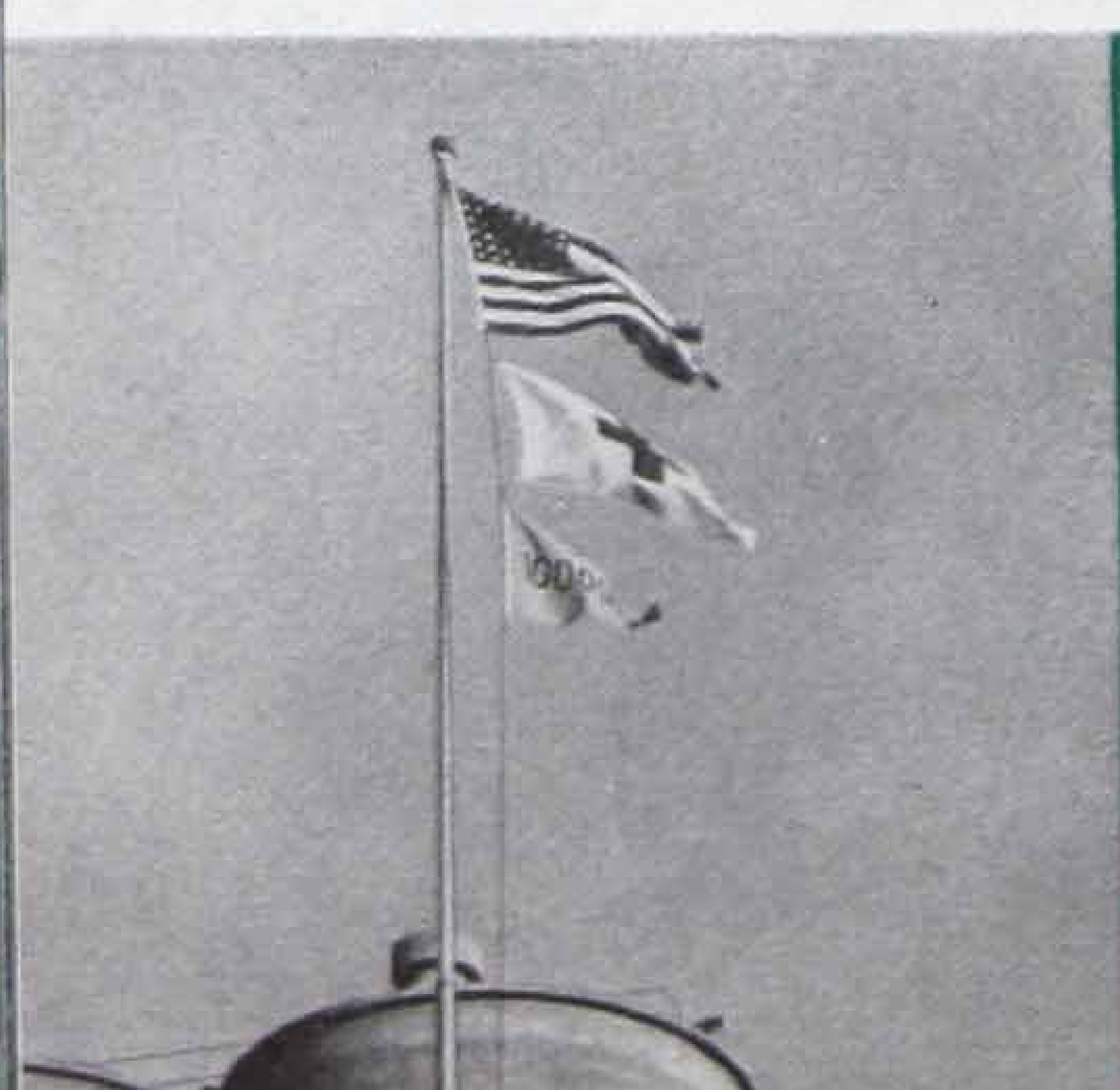
PORTLAND cement manufacturers have demonstrated that disabilities and suffering from accidental injuries can be prevented by consistent educational and engineering work. Likewise, loss of earnings and production time by employes can be reduced to a minimum. And what is good for the employes has proved good for the entire industry.

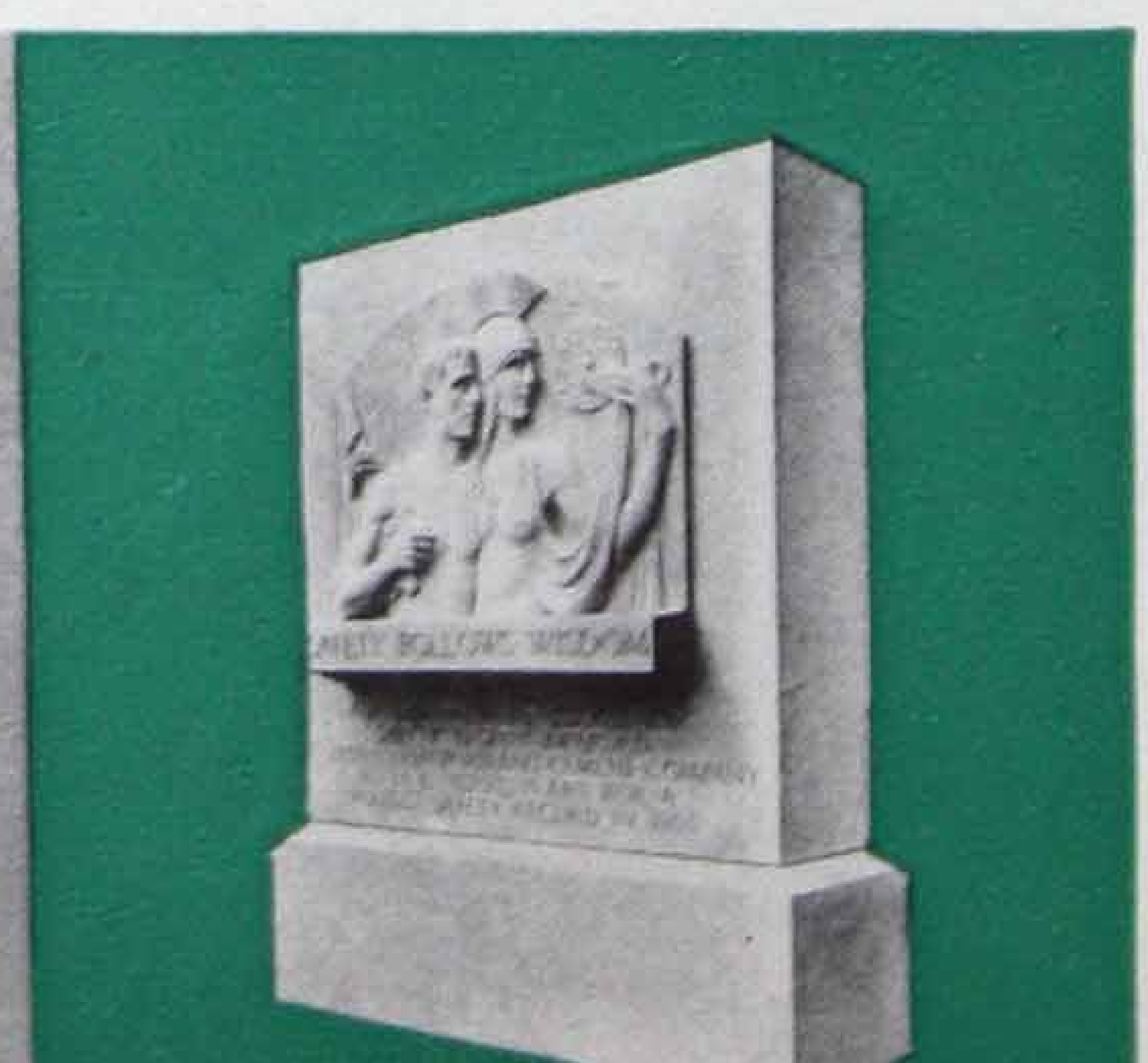
The past 30 years have seen the number of occupational injuries per million man-hours worked reduced 90 per cent in the plants of member companies of the Portland Cement Association. In that period it is estimated that thousands of lives have been saved, more thousands of permanently disabling work injuries averted, and more than 100,000 other lost-time injuries prevented as a result of Association-sponsored safety programs.

Outstanding Safety Record

For years, cement manufacture has been named by the National Safety Council as one of the safest of the heavy industries. And of the 40 basic industries studied by that organization, it is ranked among the four safest. The 1955 experience is based on reports from 156 cement plants that operated 79,184,757 man-hours. The injury frequency rate of 2.66 per million man-hours is 62 per cent below the 1955 rate for all 40 industries. And cement-making involves the admittedly hazardous operations of quarrying, mining and blasting, and the use of high-voltage electric current, intense heat and some of the world's largest moving machinery.

The cement industry's success in reducing occupational injuries results from a carefully planned and humane approach to the problem of safety. Revision of work methods through engineering studies is a basic procedure. This is combined with the provision of mechanical safeguards where needed, plus persistent safety education, safety training, and competition for low accident records among employe groups. All these phases of the accident prevention program are wholeheartedly supported by the Association members.





Left— The safety flag is flown proudly below the American flag at a cement plant. Below both is a flag signifying that the employes of this plant have worked 1,000 accident-free days. *Right*—The Portland Cement Association safety trophy.

Trophy Awarded Annually

Contributing in large measure to industry-wide interest in accident prevention is the safety trophy awarded and reawarded annually by the Association to cement mills that operate a full calendar year without a lost-time injury. In 30 years, 163 plants have operated the equivalent of 1,092 years without a lost-time accident, a safety record believed to be unparalleled by any other industry.

90 Plants Earn Membership

Ninety plants have earned the coveted right to membership in the Association's unique Thousand-Day Club, which comprises plants credited with more than 1,000 successive safe days of operation. A number have operated without lost-time accidents from 5 to 12 consecutive years, and one has a record of 17 successive years without a disabling injury.

The National Safety Council and U.S. Bureau of Mines have awarded highest honors to the Portland Cement Association for promoting safety in the plants of its member companies, and to many individual plants for perfect safety records.

accident prevention progress in the cement industry[a]

year	plants reporting	temporarily disabling injuries	permanent disabilities	fatalities	disabling injuries per million man-hours	no-accident plants: number	no-accident plants: per cent of total
1925	120	2,541	77	61	27.50	2	1.7
1926	124	2,172	67	45	23.45	2	1.6
1927	134	1,337	66	30	15.27	10	7.5
1928	136	877	75	33	11.48	17	12.5
1929	138	686	55	37	10.28	26	18.8
1930	128	420	48	18	6.97	43	33.6
1931	100	197	23	17	6.22	42	42.0
1932	112	125	16	5	5.27	42	37.5
1933	116	120	23	7	5.70	54	46.6
1934	127	185	31	16	7.14	43	33.9
1935	124	170	41	8	6.84	43	34.7
1936	120	247	37	17	7.67	36	30.0
1937	118	176	39	16	5.17	38	32.2
1938	116	136	29	11	4.66	51	44.0
1939	125	147	31	6	4.26	47	37.6
1940	129	178	34	12	4.90	47	36.4
1941	129	261	45	12	5.99	33	25.6
1942	131	358	43	43	7.58	24	18.3
1943	130	349	33	13	7.78	30	23.1
1944	129	292	28	15	8.47	33	25.6
1945	128	289	29	7	7.99	40	31.3
1946	136	403	52	10	7.88	30	22.1
1947	134	390	58	21	7.23	30	22.4
1948	136	398	52	21	6.81	24	17.6
1949	137	287	57	17	5.18	42	30.7
1950	141	279	47	12	4.83	44	31.2
1951	142	248	48	13	4.22	44	31.0
1952	146	270	54	20	4.64	48	32.9
1953	148	243	34	14	3.81	55	37.2
1954	152	205	45	6	3.38	66	43.4
1955	156	170	29	12	2.66	64	41.0

(a) Source: Accident Prevention Bureau of the Portland Cement Association, covering accident experience in member-company plants in the United States and Canada.

uses of portland cemen

The Highway Job Ahead (page 39) . . .

tells why the 3,366,000 miles of roads and streets in the United States are facing an alarming crisis. The difficulties in meeting the problems of highway maintenance, replacement and improvement are pointed out, along with an explanation of what is being done by the federal government and various state highway departments to provide facilities for today's traffic needs as well as for the expected future growth in motor-vehicle traffic.

Early Concrete Pavements (page 46) . . .

gives facts about some historic concrete pavements in the United States and Canada and is illustrated with photographs of some early concrete streets.

Highway Research (page 48) . . .

describes what highway engineers and research scientists are doing through various public and private agencies and organizations to lower the cost and lengthen the service life of roads and streets so that road users will get the utmost in safe and convenient travel for what they pay in motor-fuel and other taxes.

Freeways (page 52) . . .

explains what freeways are, where they should be built, and how traffic authorities determine the need for them in both urban and rural areas.

Highway Financing (page 54) . . .

describes the federal-aid highway program over a period of years and defines and explains diversion of highway revenues. The entire picture of federal-aid legislation is presented, together with a brief discussion of highway financing methods employed by various states.

Highway Safety (page 59) . . .

points out the various steps being taken to cut traffic accidents, tells what is being accomplished and by what means, and discusses the organizations that have contributed to highway safety.

Soil-Cement (page 61) . . .

describes the present-day uses of low-cost soil-cement, the reasons for its rapid development, and the soil-cement process, which makes use of about 9 parts of soil found on the site to be improved, 1 part of portland cement, and sufficient water to permit compaction of the mixture into a stable and durable material.

Concrete for Airports (page 65) . . .

tells how concrete meets the exacting construction needs of modern airports, which must keep pace with rapid advances in aircraft design, particularly with the growing use of jet planes by the military and their expected early extension into the commercial airline field. It also points out the importance of runway construction in airport safety and explains federal assistance offered for the construction and maintenance of airports.

and concrete

Reinforced Concrete (page 68) . . .
traces the development of the use of steel reinforcement (high in tensile strength) in combination with concrete (high in compressive strength) to produce structural members capable of sustaining heavy loads.

Architectural Concrete (page 70) . . .
is construction in which the concrete left exposed determines the architectural appearance of the building. This article summarizes the history and gives examples of architectural concrete in this country from its beginning to its present widespread use for all architectural styles.

Tilt-Up (page 73) . . .
is a method of construction in which concrete walls are cast in a horizontal position and then tilted into place. In addition to describing the tilt-up construction process, this article explains the types of construction best adapted to tilt-up and the architectural effects that may be achieved with it.

Prestressed Concrete (page 74) . . .
discusses the points of difference between conventional reinforced concrete and this newer development in the structural field. Prestressing makes possible concrete bridges, roofs and structural members with longer unsupported spans than ever before. Two methods of prestressing—*pre*tension and *post*tension—are discussed, and the history and development of prestressed concrete are outlined.

Concrete Bridges (page 77) . . .
discusses and gives examples of the four main types of reinforced concrete bridges (rigid frame, slab, girder and arch) and tells the story of the development of concrete bridges in the United States.

Railway Uses of Concrete (page 80) . . .
points out how railroads are today using large quantities of cement grout and concrete to improve railway construction and to reduce maintenance and replacement costs. Concrete is used in more than 160 ways in the operation and maintenance of America's 220,000 miles of railroad track.

Concrete Shell Roofs (page 82) . . .
explains how long-span, high-ceilinged reinforced concrete roofs are making it possible to design and build gymnasiums, aircraft hangars and industrial buildings with large amounts of clear, unobstructed floor space. Usually only 3 to 3½ in. in thickness, these concrete shell roofs can be designed to span long distances without the support of interior columns, below-ceiling beams or trusses.

Concrete for Housing (page 84) . . .
points out the growing trend toward greater use of concrete in home construction and the reasons for this trend. Concrete masonry and reinforced concrete homes are described, as well as concrete floors, footings, foundations and basements.

Farm Uses of Concrete (page 88) . . .
describes many of the ways in which concrete makes the work of the farmer and his family easier while increasing farm profits. Among the topics discussed are the uses of concrete in the farmer's home, dairy barn, milkhouse, silo, feeding floor and barnyard pavement, farrowing house, poultry house, and septic-tank sewage-disposal system.

Concrete in Conservation (page 93) . . .
points out that widespread concern over destruction of natural resources has led to increased efforts in the control and use of water. This article tells how concrete —by virtue of its use in the construction of dams, reservoirs, levees, flood walls, spillways and similar structures—is playing an important role in the restoration, preservation and sound development of the nation's natural resources.

Concrete Masonry (page 98) . . .
is a term applied to block and brick building units molded of concrete and laid into a wall. This article describes the manufacturing process and uses of concrete masonry units. It also discusses the modular coordination method of building, firesafety tests conducted by Underwriters' Laboratories, Inc., and the sound-absorption qualities of concrete masonry.

Concrete Pipe (page 101) . . .
tells how thousands of miles of concrete pipelines are serving the people of the United States in many vital ways. It discusses concrete pressure pipe, which transport water to our cities; concrete sewer pipe, which contribute immeasurably to community sanitation and health; and concrete irrigation pipe, which are used to convert semiarid regions into productive farm land.

Precast Structural Members (page 104) . . .
are being used in increasing numbers and today have found an important place in almost every field of construction, for example, in rail-highway grade crossings. This article defines them and discusses uses of the major precast structural members, including concrete joists, piles, floor and roof slabs, and wall panels.

Portland Cement Grouting (page 106) . . .
is widely used for stabilizing and increasing the load capacity of railroad subgrades and roadbeds, restoring old stone masonry, strengthening construction joints and improving foundations for dams. Because of its fluid consistency, it may be injected into places not easily accessible, and often obviates costly excavation and replacement.

Oil-Well Cementing (page 109) . . .
explains how portland cement grout is used to protect the vital casing, through which oil flows, against breakage, collapse, corrosion or water seepage.

Asbestos-Cement Products (page 110) . . .
include a wide range of construction materials, the best known of which are siding, roofing, shingles, corrugated sheets, flat building boards and conduits. This article describes the uses of asbestos-cement products and the "wet" and "dry" processes by which they are manufactured.

the highway job ahead

AMERICA'S highways today face an alarming crisis. More than 61 million cars and trucks traveled in excess of 590 billion vehicle-miles on the nation's highways in 1955. This represents an increase in motor vehicles of 78 per cent and an increase in vehicle-miles of 73 per cent since 1946. And studies of traffic trends show that these figures will continue to increase.

Today's highway system is completely inadequate to cope with these staggering increases in vehicles and miles traveled. To expedite such a flow of vehicles, more multilane highways must be built and the various scattered freeways connected and expanded into an integral system of highways that will be economically and structurally sound—a system designed for safe travel not only today but in the future as well.

Thus, an important part of the task ahead of highway engineers is to design and build roads that not only are adequate for present needs but have sufficient durability and capacity to carry increasing traffic for many years to come. Highways built 25 or 30 years ago, while adequate for the traffic of that day, became obsolete when heavier vehicles and unforeseen volumes of traffic developed.

States Develop Programs

An increasing number of states since World War II have followed the lead of California in planning for and working out practical road-building programs in anticipation of traffic needs of the next 15 to 20 years—programs that incorporate advanced principles of design developed by engineers through long-range planning based on factual surveys. The following 35 states have made or are making long-range highway programs covering all roads and streets in the state:

Arizona	Kansas	Montana	South Dakota
California	Kentucky	Nebraska	Tennessee
Colorado	Louisiana	New Hampshire	Utah
Connecticut	Maine	New York	Vermont
Florida	Maryland	North Carolina	Virginia
Idaho	Massachusetts	North Dakota	Washington
Illinois	Michigan	Ohio	West Virginia
Indiana	Minnesota	Oregon	Wisconsin
Iowa	Mississippi	Rhode Island	

The application of accurate, scientific methods of determining traffic growth is a recent development. Highway engineers are applying data on traffic trends

in advance of construction so that new roads will not become obsolete before their term of life expectancy has expired.

Development of rational planning of highways received its greatest impetus when, in 1934, Congress authorized the Public Roads Administration to allocate $1\frac{1}{2}$ per cent of federal-aid funds to states for engineering planning.

Summed up briefly, the ultimate aim of the planning surveys was to learn how extensive a system of highways the people of each state needed and could afford.

More recent steps in the direction of state and federal cooperation for an improved road system have been the Federal-Aid Highway Acts passed by Congress since 1944 (see page 54). These acts have authorized much larger appropriations for the postwar construction of highways and bridges. They have also inaugurated action on a 41,000-mile National System of Interstate and Defense Highways that will connect 42 state capitals and 90 per cent of all cities of more than 50,000 population. But the job of modernizing this system and improving its urban connections through the heart or around the edges of great cities is only beginning.

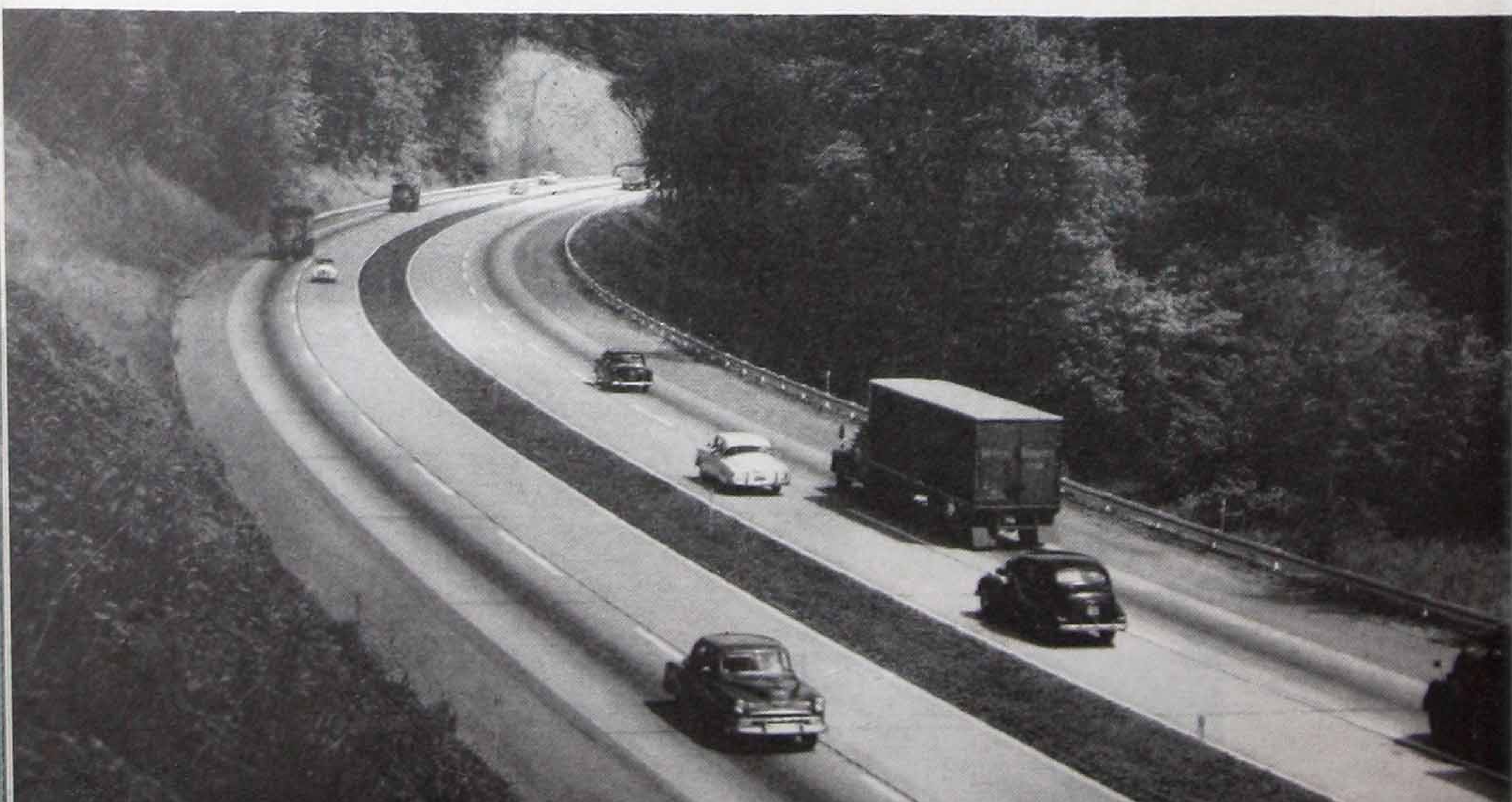
Upkeep Biggest Job

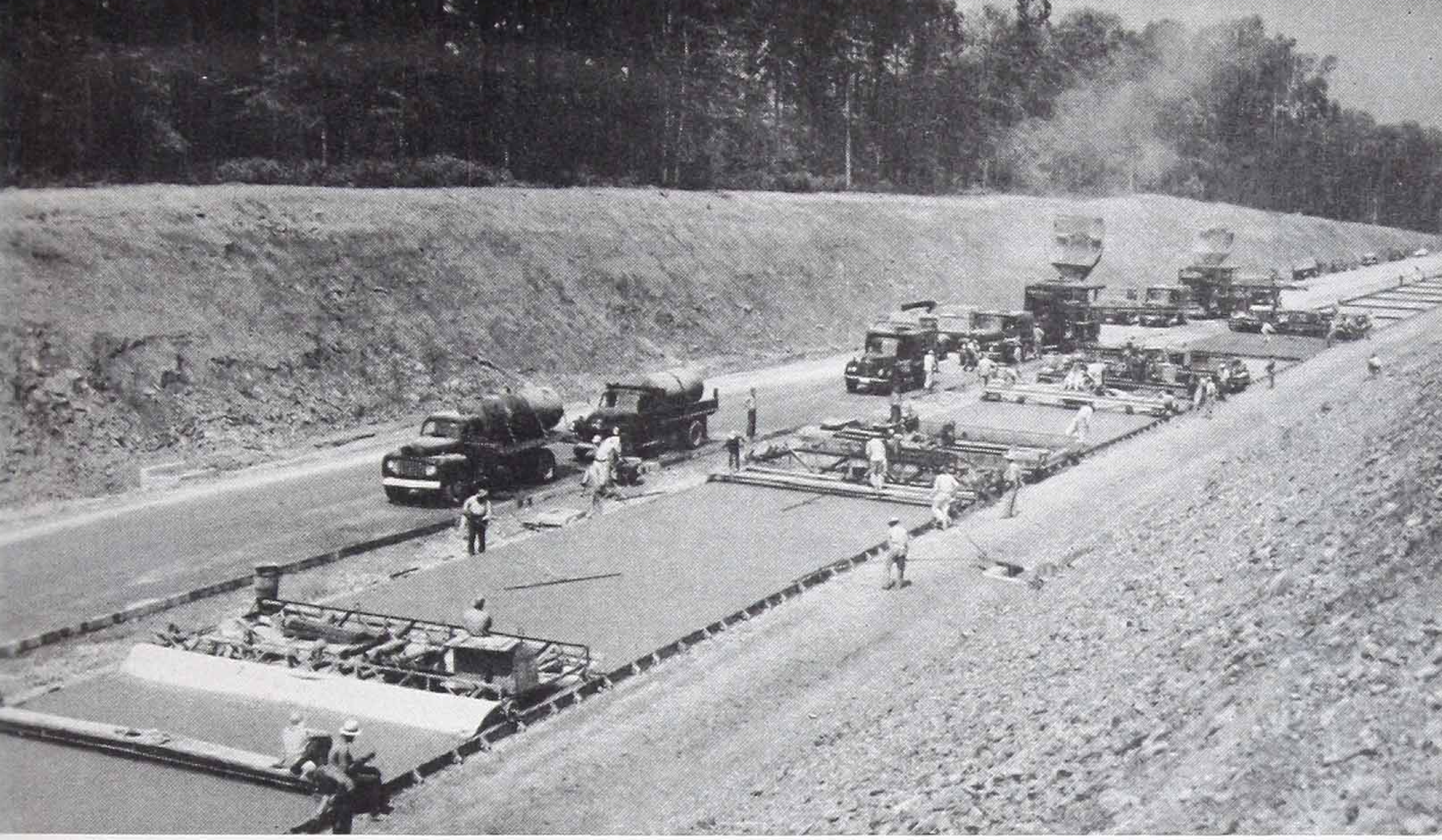
Even the big and important job of providing new expressways is dwarfed in comparison with the staggering task of keeping existing roads and streets in safe operating condition. Thomas H. MacDonald, former commissioner of public roads, points out that there are only two methods of keeping roads and streets in continuous operation. The first is by intensive maintenance; the second, by replacement and improvement. The size of this job can be seen in the records of many state highway departments showing that roads are wearing out at the rate of 40,000 miles a year.

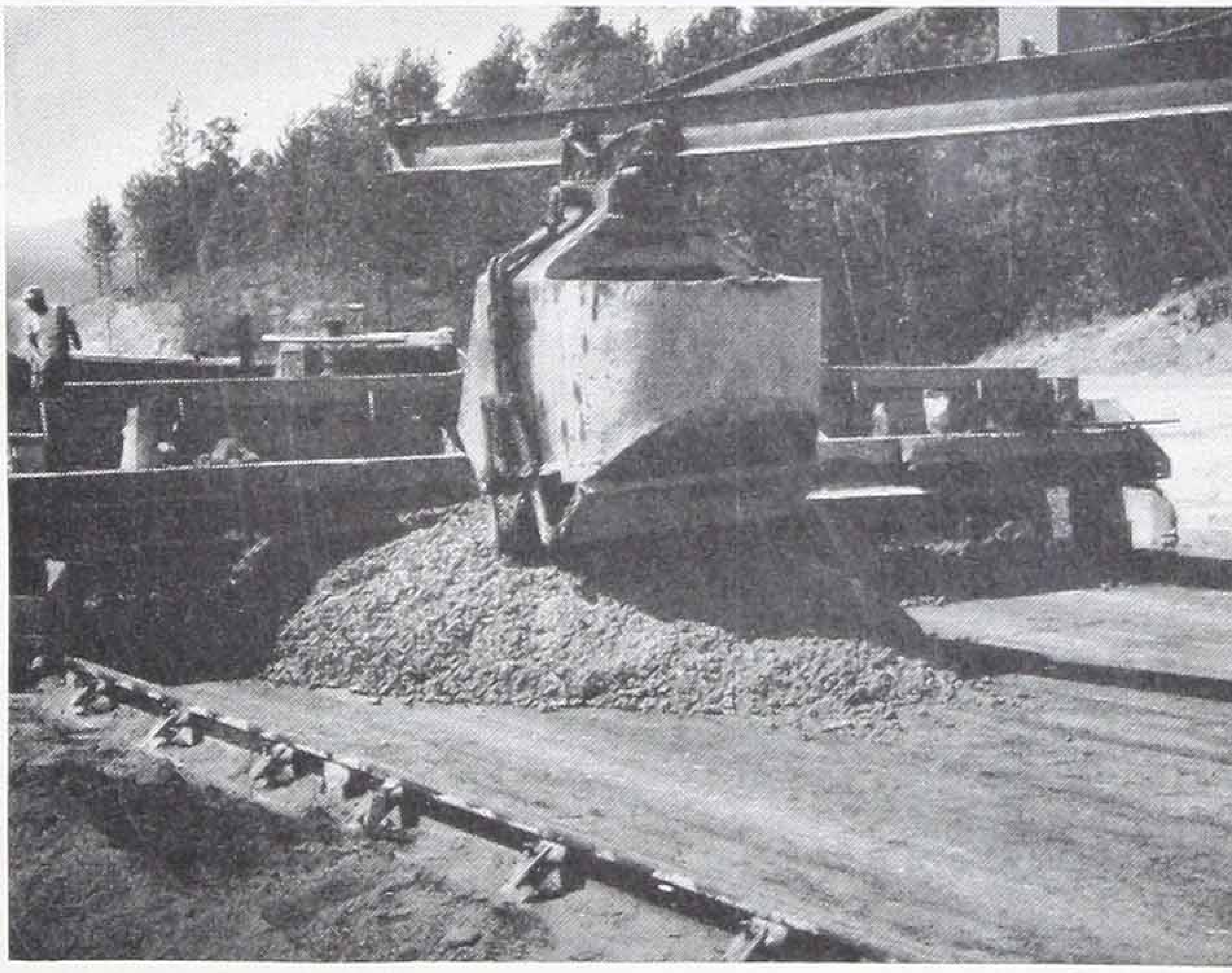
At the 1948 through 1954 average rate of replacement of obsolete roads under the control of the state highway departments, a period of more than 20 years will be required to rehabilitate these systems.

If this period is added to the average age of today's roads (12 years), it must

Commercial and pleasure vehicles move swiftly and safely on divided concrete highways such as this four-lane section of the Pennsylvania Turnpike.







All states are engaged in programs of extending and improving their present highway facilities. This construction train is placing a ribbon of concrete in the modernization program of our national highways.

be obvious, says former Commissioner MacDonald, that maintenance alone cannot possibly hold these roads in service and that new construction, based on the traffic needs of today and tomorrow, must be expanded. This is being done.

Parking Problem Urgent

There is yet another important phase of raising highway performance to the level of the efficiency attained by the automobile, and that is to solve the parking problem in metropolitan areas. The usual methods of time-limited curb parking, parking meters and too few, scattered parking lots are obviously inadequate. In fact, much of the existing curb parking practice defeats its own purpose by adding to traffic chaos rather than relieving it.

concrete pavement awards in the United States, 1909–1955 in square yards

year	roads	streets and alleys	airports	total
1909[a]	66,687	969,338	---	1,036,025
1910	151,148	790,511	---	941,659
1911	291,077	1,148,114	---	1,439,191
1912	1,869,486	3,511,732	---	5,381,218
1913	3,339,185	4,254,584	---	7,593,769
1914	10,608,421	5,130,742	---	15,739,163
1915	12,050,909	6,546,800	---	18,597,709
1916	15,906,801	8,276,154	---	24,182,955
1917	15,333,087	6,438,092	---	21,771,179
1918	12,990,519	3,881,765	---	16,872,284
1919	41,335,342	12,124,592	---	53,459,934
1920	29,326,689	9,721,946	---	39,048,635
1921	43,862,503	12,301,633	---	56,164,136
1922	58,301,413	20,784,292	---	79,085,705
1923	50,893,999	27,043,773	---	77,937,772
1924	58,105,921	34,134,240	---	92,240,161
1925	63,895,104	40,174,237	---	104,069,341
1926	64,978,458	48,920,669	---	113,899,127
1927	77,232,917	53,030,516	---	130,263,433
1928	93,531,487	54,546,421	---	148,077,908
1929	92,816,794	47,203,957	---	140,020,751
1930	108,008,062	37,813,593	---	145,821,655
1931	111,989,850	22,927,002	---	134,916,852
1932	87,165,260	10,397,690	---	97,562,950
1933	40,097,069	8,295,937	430,774	48,823,780
1934	30,203,993	14,903,522	67,246	45,174,761
1935	30,971,959	12,677,321	147,271	43,796,551
1936	41,267,977	16,425,379	728,068	58,421,424
1937	39,945,532	14,581,566	518,588	55,045,686
1938	36,900,856	18,345,456	1,610,358	56,856,670
1939	29,852,670	19,369,260	1,065,772	50,287,702
1940	38,123,867	18,379,298	5,857,512	62,360,677
1941	34,880,387	19,877,331	29,213,344	83,971,062
1942	23,654,271	17,668,113	92,900,110	134,222,494
1943	9,662,819	9,071,960	52,345,892	71,089,671
1944	8,468,216	5,827,461	18,469,482	32,765,159
1945	8,218,419	5,140,518	7,346,497	20,705,434
1946	24,689,500	12,129,582	2,820,883	39,639,965
1947	21,861,087	14,663,207	1,582,552	38,106,846
1948	25,412,655	19,383,408	2,736,485	47,532,548
1949	24,965,362	18,543,805	2,735,659	46,244,826
1950	28,330,381	27,023,159	3,174,771	58,528,311
1951	24,921,240	23,757,435	14,063,399	62,742,074
1952	27,019,483	25,809,478	9,636,710	62,465,671
1953	42,355,652	26,272,711	9,939,915	78,568,278
1954	38,026,658	29,270,295	18,034,085	85,331,038
1955	40,733,279	35,104,099	17,621,234	93,458,612
totals	1,724,614,451	884,592,694	293,055,607[b]	2,902,262,752

(a) Includes all previous years.
(b) Airport yardage through 1932 was included in streets and alleys.

According to the International City Managers' Association, more than 500 cities in the United States already are operating municipal off-street parking lots. Several large cities such as Chicago, San Francisco, Boston, Detroit and Washington, D.C., are encouraging private enterprise to construct underground parking garages in or near the business districts or are doing the job themselves. New York and several other cities are trying to solve the parking problem by the construction of skyscraper mechanical garages with elevators instead of the usual ramp system found in two- and three-story garages.

Cooperation Necessary

The creation of an integrated highway system that will meet the needs of present and future traffic hinges on the prerequisites of thorough research, long-range planning and adequate financing.

Such a system can be attained only through the full cooperation of local, state and federal officials, together with the driving public who pay the cost. Highway engineers are now in a position to apply facts obtained by research to the construction of a safe, economical and efficient network of highways that will serve America's rapidly expanding traffic requirements, and at the same time will bind the nation into an ever more closely knit community.

Traffic interchanges like this one on the Cross Island Parkway, New York, are proving to be one answer to safer and speedier handling of traffic in and around our cities.

—Photograph courtesy of Triborough Bridge and Tunnel Authority and Skyviews, Inc.

concrete street pavement awards in 101 U.S. cities with populations of more than 100,000

areas covered by Portland Cement Association district offices

	cities	population 1950	sq.yd. of concrete str before 1955	durin 195
5 cities with population of more than 1,000,000	Chicago	3,620,962	16,915,219	127,7
	Detroit	1,849,568	11,966,061	594,3
	Los Angeles	1,970,358	26,630,309	396,3
12 cities with population between 500,000 and 1,000,000	Baltimore	949,708	8,295,389	449,4
	Boston	790,863	947,180	30,0
	Buffalo	580,132	720,371	48,4
	Cincinnati	503,998	5,800,429	391,1
	Cleveland	914,808	2,525,686	196,1
	Houston	596,163	17,974,287	3,488,6
	Milwaukee	637,392	6,654,771	436,6
21 cities with population between 250,000 and 500,000	Akron	274,605	424,380	43,9
	Atlanta	331,314	4,708,949	122,8
	Birmingham	326,037	2,006,520	2,2
	Columbus	375,901	713,493	31,4
	Dallas	434,462	11,561,636	2,351,9
	Denver	415,786	604,130	1,7
	Fort Worth	278,778	745,868	43,8
	Indianapolis	427,173	3,680,169	607,6
	Jersey City	299,017	190,576	——
	Kansas City, Mo.	456,622	6,269,984	68,3
	Long Beach, Calif.	250,767	2,673,872	58,9
63 cities with population between 100,000 and 250,000	Albany, N.Y.	134,995	1,096,427	4,5
	Allentown	106,756	875,384	20,0
	Austin	132,459	775,470	——
	Baton Rouge	125,629	931,494	30,5
	Bridgeport	158,709	8,400	——
	Cambridge	120,676	180,343	——
	Camden	124,055	529,503	——
	Canton	116,912	48,599	——
	Charlotte, N.C.	134,042	830,359	11,2
	Chattanooga	131,041	726,552	——
	Corpus Christi	108,287	590,300	——
	Dayton	243,872	1,165,544	——
	Des Moines	177,965	2,589,642	105,7
	Duluth	104,511	2,130,659	——
	Elizabeth	112,817	576,512	——
	El Paso	130,485	65,072	——
	Erie	130,803	521,822	90,3
	Evansville	128,636	955,373	148,1
	Fall River, Mass.	111,759	145,534	——
	Flint	163,143	868,662	436,9
	Fort Wayne	133,607	1,354,964	90,8
	Gary	133,911	977,454	1,0
	Grand Rapids	176,515	939,574	3
	Hartford, Conn.	177,397	182,546	——
	Jacksonville	204,517	704,948	——
	Kansas City, Kan.	129,553	2,108,217	19,5
	Knoxville	124,769	697,573	——
	Little Rock	102,213	1,164,873	41,2
	Miami	249,276	445,081	——
	Mobile	129,009	1,249,753	27,8
	Montgomery, Ala.	106,525	215,109	——
	Nashville	174,307	272,948	12,9

(a) Corrected total yardage.

grand t

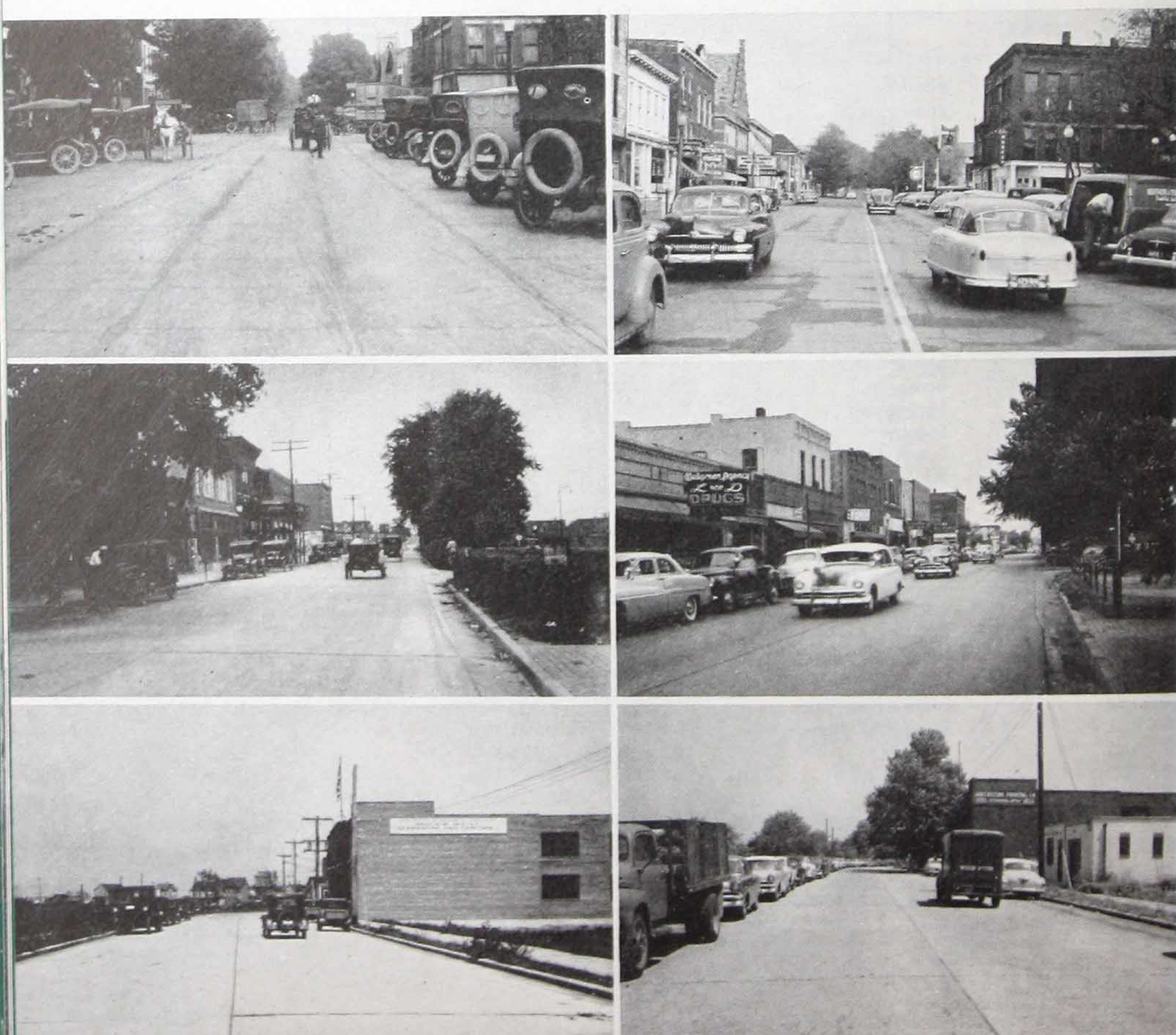
avement
total to 2/31/55
7,042,941
2,560,456
7,026,666
8,744,820
977,180
768,771
6,191,621
2,721,864
1,462,923
7,091,451
468,378
4,831,774
2,008,800
744,905
3,913,581
605,880
789,755
4,287,777
190,576
6,338,314
2,732,797
1,100,927
895,384
775,470
961,994
8,400
180,343
529,503
48,599
841,564
726,552
590,300
1,165,544
2,695,364
2,130,659
576,512
65,072
612,158
1,103,520
145,534
1,305,657
1,445,790
978,514
939,876
182,546
704,948
2,127,745
697,573
1,206,135
445,081
1,277,643
215,109
258,900

		sq.yd. of concrete street pavement		
cities	population 1950	before 1955	during 1955	total to 12/31/55
New York	7,891,957	11,896,749	589,590	12,486,339
Philadelphia	2,071,605	3,184,229	57,486	3,241,715
totals	———	70,592,567	1,765,550	72,358,117
Minneapolis	521,718	1,638,132	252,757	1,890,889
New Orleans	570,445	2,864,693	205,230	3,069,923
Pittsburgh	676,806	2,558,749	91,977	2,650,726
St. Louis	856,796	3,126,056	132,370	3,258,426
Washington	802,178	7,002,835	146,470	7,149,305
totals	———	60,108,578	5,869,321	65,977,899
Louisville	369,129	1,103,179	148,925	1,252,104
Memphis	396,000	2,221,588	2,817	2,224,405
Newark	438,776	693,834	———	693,834
Omaha	251,117	2,738,085	437,742	3,175,827
Rochester, N.Y.	332,488	470,769	———	470,769
St. Paul	311,349	1,423,267	20,799	1,444,066
San Antonio	408,442	707,310	———	707,310
San Diego	334,387	5,090,583	229,740	5,320,323
Seattle	467,591	13,653,231 [a]	351,400	14,004,631
Toledo	303,616	2,963,766	275,362	3,239,128
totals	———	64,645,189	4,799,745	69,444,934
New Bedford, Mass.	109,033	15,372	———	15,372
New Haven	164,443	436,169	———	436,169
Norfolk	213,513	970,326	39,308	1,009,634
Oklahoma City	243,504	5,511,296	610,420	6,121,716
Pasadena	104,577	488,096	8,930	497,026
Paterson	139,336	228,009	———	228,009
Peoria	111,856	2,189,082	36,832	2,225,914
Phoenix	106,818	994,899	———	994,899
Providence	248,674	92,011	———	92,011
Reading	109,320	597,390	———	597,390
Richmond	230,310	855,284	19,910	875,194
Salt Lake City	181,718	568,638	———	568,638
Savannah	119,638	1,085,356	7,528	1,092,884
Scranton	125,536	106,593	———	106,593
Shreveport	127,206	1,524,268	229,796	1,754,064
Sommerville, Mass.	102,254	40,673	———	40,673
South Bend	115,911	1,406,804	67,055	1,473,859
Spokane	161,721	699,916	———	699,916
Springfield, Mass.	162,601	144,286	———	144,286
Syracuse	220,583	293,588	———	293,588
Tacoma	143,673	1,701,080	37,366	1,738,446
Tampa	124,681	314,778	———	314,778
Trenton	128,009	852,193	———	852,193
Tulsa	182,740	5,072,380	754,143	5,826,523
Utica	101,531	288,792	———	288,792
Waterbury, Conn.	104,477	267,000	———	267,000
Wichita	168,279	5,819,622	463,779	6,283,401
Wilmington, Del.	110,356	351,228	11,760	362,988
Worcester, Mass.	201,885	221,128	———	221,128
Yonkers	152,798	462,977	———	462,977
Youngstown	168,330	979,170	80,229	1,059,399
totals	———	60,503,095	3,408,281	63,911,376
awards in 101 cities of more than 100,000 population		255,849,429	15,842,897	271,692,326

early concrete pavements

THE first concrete pavement in North America was an 8-ft. strip laid in Bellefontaine, Ohio, in 1891. The first extensive use of concrete paving in North America was in Canada. In 1907, before any other community had built more than a block or two, more than two miles was laid in Windsor, Ont. In 1909, the first mile of concrete road in the United States was built in Wayne County, Mich.

Many early concrete streets throughout the United States are still giving excellent service—even under today's much heavier loads and traffic. *Top*—This street on the public square in Bellefontaine, Ohio, was built in 1893—two years after the first concrete pavement was laid in the same city. The pavement, shown as it looked in 1921 *(left)* and 1953, is still giving good service after more than 60 years of increasingly heavy traffic. *Center*—Main St., De Soto, Mo., built in 1926, as it looked in 1927 and 1952. *Bottom*—Pierce Ave. at East State St., Camden, N.J., as it looked in 1927 and 1954.



concrete roads, streets, alleys and airports, by states 20-ft. wide pavement completed to January 1, 1956[a]

state	road miles	street and alley miles	airport miles	total miles
Alabama	1,107	1,069	314	2,490
Arizona	499	130	438	1,067
Arkansas	1,467	816	496	2,779
California	6,693	2,831	2,146	14,669
Colorado	646	474	269	1,389
Connecticut	1,338	333	37	1,730
Delaware	1,018	64	113	1,195
District of Columbia	———	380	83	463
Florida	1,029	813	1,279	3,130
Georgia	2,468	1,637	673	4,778
Idaho	119	49	81	249
Illinois	14,367	7,496	431	22,294
Indiana	7,308	2,137	333	9,830
Iowa	6,841	2,753	313	9,908
Kansas	3,148	1,953	1,831	6,931
Kentucky	1,743	963	308	3,014
Louisiana	2,906	1,733	923	5,281
Maine	283	100	111	496
Maryland	3,039	1,130	348	4,218
Massachusetts	431	681	194	1,306
Michigan	8,638	5,306	749	14,383
Minnesota	3,876	1,618	119	5,613
Mississippi	3,413	700	318	5,433
Missouri	5,751	3,093	491	8,934
Montana	33	103	38	174
Nebraska	1,711	1,356	1,043	4,109
Nevada	43	43	116	201
New Hampshire	273	83	103	461
New Jersey	3,347	3,078	194	5,311
New Mexico	103	131	367	471
New York	13,687	4,743	931	18,361
North Carolina	3,468	908	537	4,897
North Dakota	130	336	16	483
Ohio	6,633	3,997	681	10,300
Oklahoma	3,034	3,343	909	6,308
Oregon	313	898	63	1,273
Pennsylvania	8,993	3,933	193	13,139
Rhode Island	379	66	73	517
South Carolina	1,944	573	313	2,833
South Dakota	407	338	73	718
Tennessee	3,213	989	348	5,249
Texas	8,076	3,471	3,109	14,606
Utah	453	198	166	817
Vermont	293	138	9	453
Virginia	1,900	863	808	3,608
Washington	3,381	3,061	889	5,331
West Virginia	1,671	349	56	2,076
Wisconsin	6,480	3,344	139	9,963
Wyoming	13	64	56	163
totals	143,487	74,638	24,293	243,308

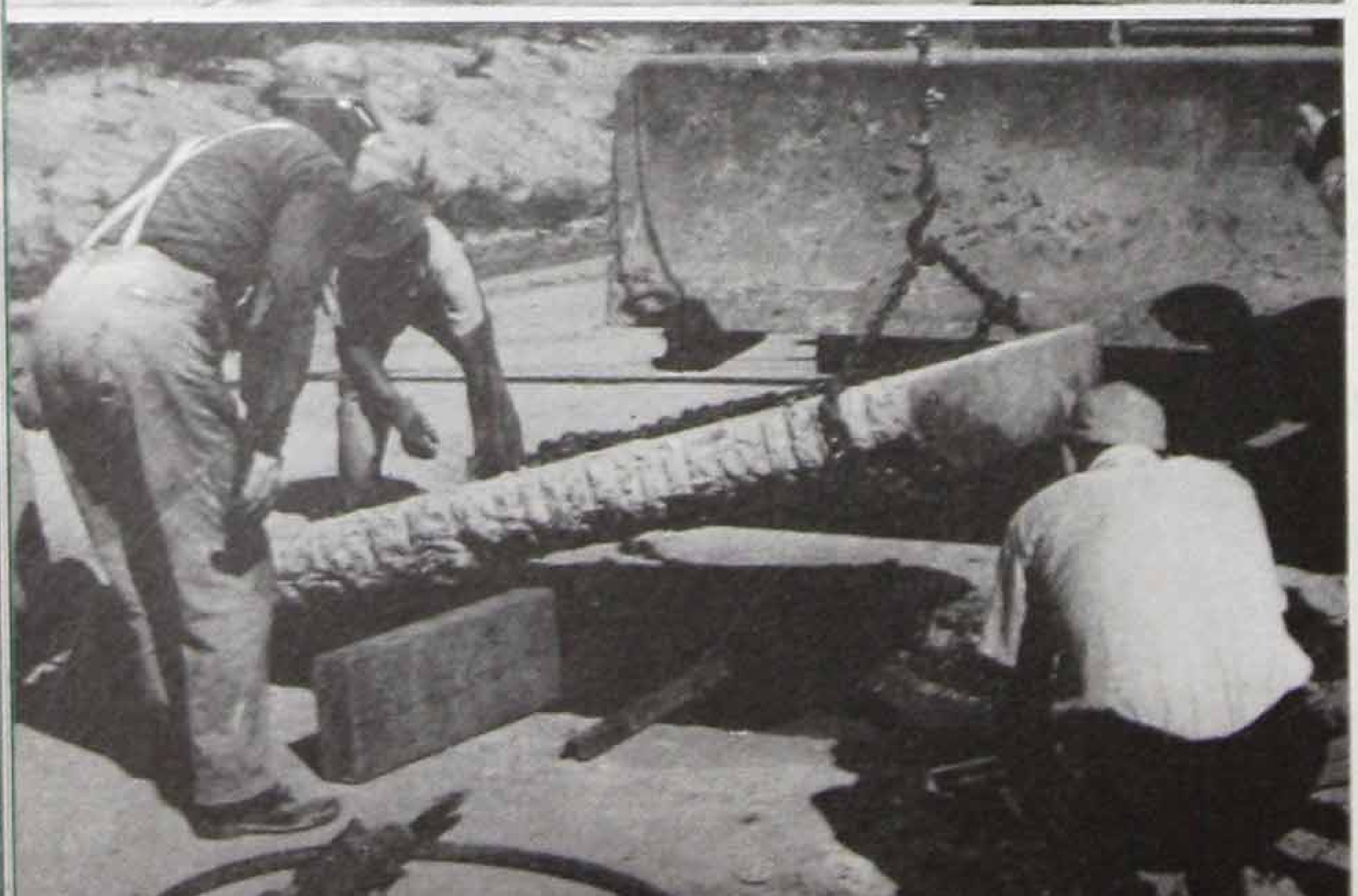
[a] Converted to mileage from square yards of pavement.

highway research

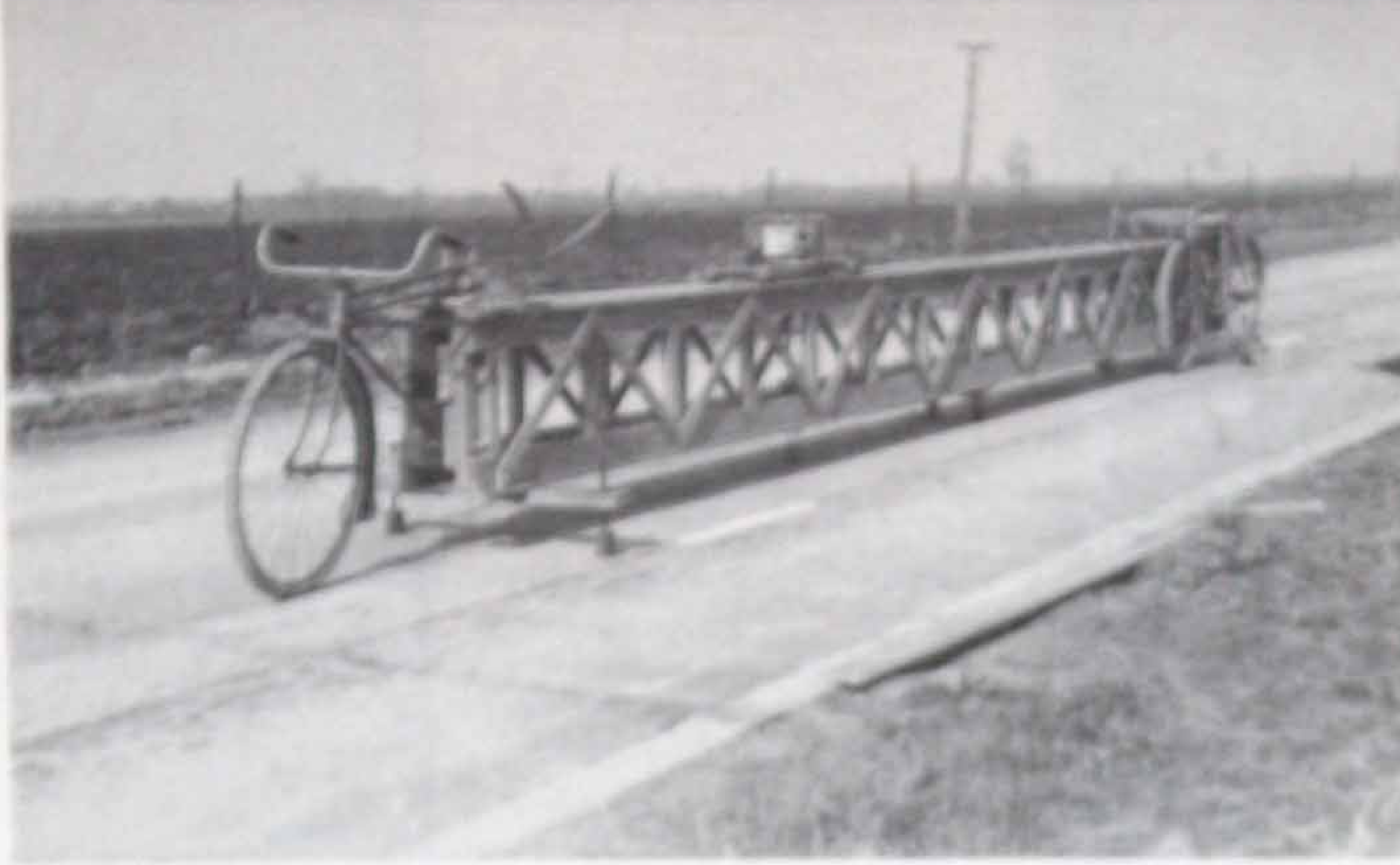
SCIENTIFIC research has supplanted guesswork in highway building. Every factor affecting the materials, construction methods, present and future use, maintenance and financing of a highway is carefully studied before the highway engineer is ready to start construction. Thus the motorist now gets a more adequate return in improved highways for his gasoline tax and license fees.

It is now recognized that roads, once regarded as mere routes cleared for overland passage from one place to another, require careful design in the same sense as does a bridge or building. If roads are to render long and economical service, they must be designed and paved for the weights and densities of the traffic they are to sustain. Studies of the effects of the volume and weight of postwar traffic reveal the importance not only of the structural nature of the pavement itself, but also of the subgrade.

Nearly all state highway departments maintain well-equipped research and testing laboratories. Many colleges and universities also carry on highway transportation research projects.



Above—An important part of highway research is the study of the effects of various types of traffic on pavements and subgrades. Weighted trucks were used to subject the Maryland Test Road to a large volume of heavy, accelerated test traffic. *Below*—A portion of a concrete paving slab is removed for further tests from a section of the Maryland Test Road.



Of historical interest is this "longitudinal profilometer" for measuring surface changes due to heavy test traffic on the Bates Test Road in 1922. A small wheel (center front section of device) traveled the length of the frame and recorded irregularities of the surface in graph form. Bicycle wheels made the device mobile.

Notable in highway research is the work of the U.S. Bureau of Public Roads, which maintains a modern experimental laboratory in Arlington, Va., where road-building materials and pavement types are tested under service conditions. Engineers of the Bureau of Public Roads cooperate with state highway officials in conducting economic and traffic studies to provide basic information as a guide to Congress in formulating legislation affecting road building. They also cooperate with the various state highway departments in conducting research projects.

Highway Research Board

The Highway Research Board of the National Research Council offers research men a medium through which to report their findings. It coordinates and publicizes the best in highway thinking to avoid duplication of effort by the state highway departments and to get at the most critical problems first. Some of the most important of these hundreds of recent, detailed studies are examination of the effects of "pumping" action on pavement slabs; studies of the behavior of different kinds of joints and subgrades under various conditions; surveys of the increasing traffic and parking congestion in cities; and studies of the behavior of air-entrained concrete (see page 24). Such is the wide scope of highway research, which is now accepted as a prerequisite to the planning and construction of modern highways.

Maryland Project Notable

Road Test One-MD is the official title of a test conducted at La Plata, Md., in the summer and fall of 1950. The project was administered and supervised by the Highway Research Board. It was a cooperative project, financed by 11 state highway departments and the District of Columbia. Other participants included the Bureau of Public Roads, the American Trucking Association, the Automobile Manufacturers Association, and the Department of the Army. Principal objective of the test was to determine relative effects of four different truck-axle loadings on a concrete pavement. That portion of the test pavement that was located on non-pumping granular material was still in excellent condition after 238,000 truck passes in each lane.

Additional tests under the auspices of the American Association of State Highway Officials are planned for concrete as well as for other pavement types.

average surface maintenance costs — 28 state primary highway systems

(items such as traffic service, snow removal, weed cutting, etc., not included)

state	number of years covered by state records	PORTLAND CEMENT CONCRETE		BITUMINOUS CONCRETE RIGID BASE		BITUMINOUS CONCR FLEXIBLE BASE	
		U.S.B.P.R.	Class J	U.S.B.P.R.	Class I	U.S.B.P.R.	Class
		Miles in service in last maint. period	Weighted aver. maint. cost per mile per year	Miles in service in last maint. period	Weighted aver. maint. cost per mile per year	Miles in service in last maint. period	Weight aver. ma cost per per yea
Arizona	20	93.6	$180.81	———	$———	28.1	$130.8
Connecticut	11	1,122.0	200.93	121.0	469.80	———	———
Florida	26	519.4	61.77	———	———	———	———
Illinois	32	11,783.3	159.72	1,559.1	130.60	———	———
Indiana	25-9/12	1,807.3	95.57	———	———	———	———
Iowa	25	5,818.2	128.97	719.5	194.29	———	———
Kansas	23	1,171.2	172.01	———	———	———	———
Kentucky	14	958.4	240.15	517.3	280.93	1,968.9	182.3
Maine	17	131.6	149.79	———	———	224.4	176.0
Massachusetts	21	503.9	118.90	———	———	458.4	105.5
Missouri	24	3,763.4	189.02	———	———	———	———
Nebraska	23	1,234.8	115.23	139.6	190.67	———	———
Nevada	25-7/12	1.0	103.70	———	———	———	———
New Hampshire	19	245.3	188.95	———	———	52.9	213.8
New Jersey	26	1,458.4	272.10	165.8	609.11	113.3	919.6
New York	30	4,451.8	175.29	70.9	325.86	50.0	485.1
Ohio	27-6/12	1,392.6	206.45	———	———	———	———
Oregon	30	310.0	214.25	———	———	815.0	360.4
Pennsylvania	10	4,203.4	256.24	1,972.9	160.41	4,312.3	170.3
Rhode Island	33	261.0	85.01	———	———	———	———
South Dakota	24	433.5	88.88	———	———	———	———
Tennessee	16	1,331.5	156.25	195.7	113.52	297.0	144.7
Texas	24	4,153.7	118.61	1,662.1	235.41	4,474.1	192.5
Wyoming	21	1.0	125.24	———	———	———	———
total miles in service, 24 states		47,150.3		7,123.9		12,794.4	
average surface maintenance costs per mile per year	22.8	$161.99		$219.52		$220.82	
New Mexico	5	53.4	68.45	———	———	392.6	102.9
Utah	12	325.0	100.95	———	———	131.9	106.0
Washington	19	1,096.2	125.04	———	———	24.8	232.8
West Virginia	11	1,045.1	156.45	———	———	446.1	238.5
total miles		49,670.0		7,123.9		13,789.8	
average cost per mile		$161.33		$219.52		$219.22	

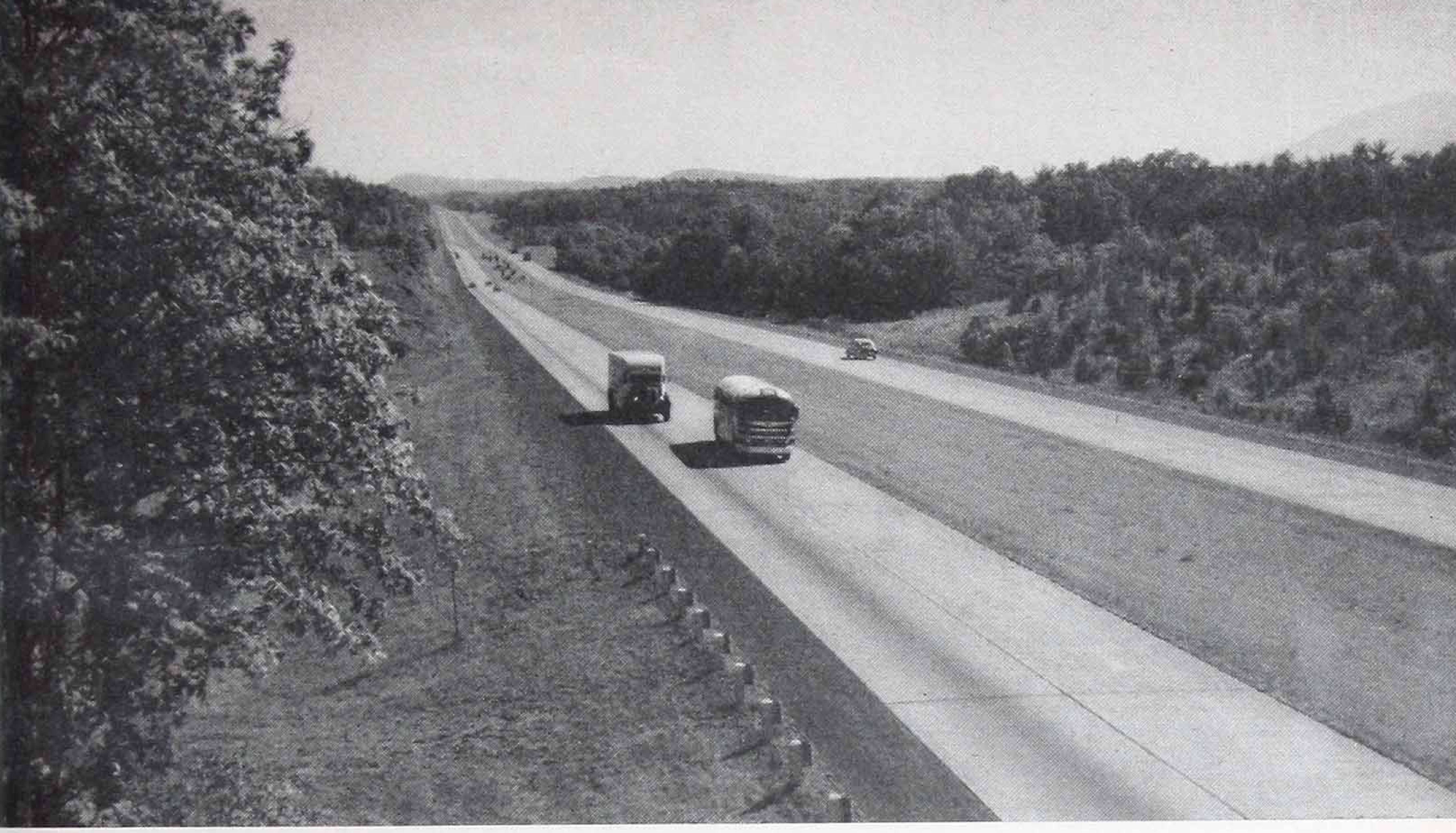
ITUMINOUS CONCRETE IGID AND FLEX. BASE		MIXED BITUMINOUS SURFACES		BITUMINOUS MACADAM		GRAVEL OR STONE		BITUMINOUS SURFACE TREATED	
U.S.B.P.R.	Class I	U.S.B.P.R.	Class G	U.S.B.P.R.	Class H	U.S.B.P.R.	Class E	U.S.B.P.R.	Class F
Miles in service in ast maint. period	Weighted aver. maint. cost per mile per year	Miles in service in last maint. period	Weighted aver. maint. cost per mile per year	Miles in service in last maint. period	Weighted aver. maint. cost per mile per year	Miles in service in last maint. period	Weighted aver. maint. cost per mile per year	Miles in service in last maint. period	Weighted aver. maint. cost per mile per year
———	$———	813.5	$252.81	———	$ ———	195.2	$282.06	2,504.9	$ 256.87
———	———	1,325.0	271.32	239.0	244.97	———	———	387.0	469.64
1,094.4	58.15	3,119.2	77.18	———	———	———	———	4,619.9	106.03
———	———	———	———	21.5	195.39	163.9	166.95	467.6	163.40
1,602.3	97.28	2,705.3	509.69	34.7	274.58	107.8	626.99	146.5	514.14
———	———	———	———	———	———	1,756.1	382.58	1,175.5	752.58
427.7	180.58	2,006.5	453.74	71.5	256.70	806.2	327.92	4,521.7	620.22
———	———	5,601.0	350.97	———	———	5,482.6	447.70	922.6	475.74
———	———	285.0	198.93	470.9	233.88	892.0	188.78	7,568.7	420.41
———	———	———	———	1,396.1	121.77	———	———	28.1	450.77
522.0	185.62	3,625.2	507.66	272.5	265.02	———	———	———	———
———	———	———	———	———	———	5,011.7	330.36	3,051.0	318.76
———	———	3,474.3	91.62	———	———	289.8	173.85	———	———
———	———	———	———	270.0	187.05	109.7	201.76	3,038.2	398.45
———	———	———	———	17.8	1,783.67	———	———	63.9	1,242.15
———	———	2,415.6	283.97	1,439.9	467.59	512.8	667.64	12.5	414.71
4,270.0	299.74	7,928.9	545.84	376.4	321.60	1,140.4	493.19	1,313.2	547.97
———	———	———	———	1,276.0	452.30	129.0	346.05	2,280.0	603.89
———	———	1,758.2	152.49	———	———	125.4	111.12	———	———
145.5	227.06	———	———	336.5	95.13	———	———	———	———
———	———	3,532.6	447.69	———	———	2,248.6	278.73	———	———
———	———	———	———	144.8	120.77	440.4	306.65	2,819.6	331.91
———	———	29,307.3	181.10	———	———	123.7	306.44	———	———
———	———	4,878.1	149.51	———	———	———	———	———	———
8,062.7		72,775.7		6,367.6		19,535.3		34,920.9	
$229.92		$285.28		$352.04		$373.73		$394.20	
———	———	2,307.6	184.32	1,063.0	113.25	———	———	609.4	140.28
———	———	———	———	1,320.7	198.31	5.0	186.29	1,247.6	125.26
———	———	———	———	254.4	316.47	———	———	2,277.2	216.81
———	———	———	———	436.6	151.98	665.9	265.12	1,709.3	286.87
8,062.7		75,083.3		9,442.3		20,206.2		40,764.4	
$229.92		$284.12		$348.76		$364.06		$384.89	

freeways

FREEWAYS are controlled-access highways of four or more lanes on which opposing traffic streams are separated by a median strip and cross-traffic is eliminated by grade separations. Constructed for through traffic, they generally exclude pedestrians and connect with important arterials by traffic interchanges that have acceleration and deceleration lanes. Their purpose is to facilitate the movement of heavy volumes of traffic between, through and around cities—and to do it safely. Needed in both rural and urban areas, they are of particular value as time- and life-savers in metropolitan districts.

The case for freeways and expressways can be simply put: without them the American transportation system will be strangled by twentieth-century traffic attempting to move on nineteenth-century roads and streets. Today in the business districts of many of our modern cities, motorists move at a pace slower than that of the horse and buggy which 40 years ago traveled the same route.

Traffic bottlenecks in our overcrowded cities are being relieved or eliminated by modern concrete expressways like this one in Dallas, Texas.



Unobstructed view and a median strip that separates opposing traffic are important safety precautions exemplified in the New York Thruway.

While the need for freeways is more dramatically demonstrated by traffic congestion in the larger cities, these highways are no less a necessity on many dangerously overcrowded routes between cities. It has been amply proven that multilane facilities not only expedite intercity movement of people and commodities but also reduce accidents.

According to the American Association of State Highway Officials, a divided highway is needed when traffic reaches 700 vehicles per hour.

Multilane highways are not designed on the basis of present needs alone; they are built to carry traffic of the future as well. During the period 1950–1955, travel increased by more than 25 billion vehicle-miles per year. Current traffic of 600 billion vehicle-miles per year is expected to increase to approximately 700 billion per year by 1960.

A high percentage of traffic is concentrated on a relatively small mileage of roads and streets. For these heavily traveled routes, the safest, most durable pavement is needed. A modern, heavy-duty concrete pavement will last 50 years—more than twice as long as any other type. And state highway department records show that the cost of maintaining concrete pavement is from 26 to 58 per cent less than for other types. (See page 50.)

Safety is designed into freeways by provisions for long sight distances, easy curves, divided lanes and grade separations. The pavement type is also of great importance. The uniformly high skid-resistance of concrete, wet or dry, and its nighttime visibility, even surface and low crown are built-in safety features that have contributed to its use for 76 per cent of all urban and 71 per cent of all rural freeways.

highway financing

THE federal government is vitally interested both in a modern, coordinated highway network for interstate commerce and for national defense and in adequate secondary roads. It has provided federal aid since 1916 to build primary state highway systems, connected at state borders to form an integrated network of national highways.

Pattern of Federal Aid Established

The modern concept of federal aid for highways began with the Federal-Aid Road Act of 1916, which established the framework within which federal aid has since been administered. This Act required the federal government to cooperate with the state highway departments; set up a formula for apportioning federal funds on the basis of area, population and mileage of rural delivery routes; and required states to match federal funds on a 50-50 basis. The 1916 Act also established the Office of Public Roads to administer federal funds.

The Federal-Aid Highway Act of 1921 required all states to designate a federal-aid system, to consist of not more than 7 per cent of their rural highway mileage. Federal-aid funds were to be expended only on these roads, the most important in each state.

Other extensions of the original Federal-Aid Act provided matching funds in varying amounts for each fiscal year through 1933. Emergency relief grants were made for highway construction during the depression years of fiscal 1933, 1934 and 1935.

Regular federal-aid authorizations were resumed in 1936 and have continued without interruption except for the war years of 1944 and 1945, and the year 1949. The Act of 1944, passed after careful study by Congress, which authorized funds for the first three postwar years (1946–1948), contained a number of new and important provisions. It called for designation of a federal-aid secondary system. For the first time it authorized funds separately for urban extensions of the primary system and the secondary system. It called for designation of a 40,000-mile system of the most important and heavily traveled roads in the country to be known as the National System of Interstate Highways. Final adoption of this system was approved in the Act of 1947.

The growing importance of the interstate system was recognized in the Acts of 1950 and 1952. The 1950 Act permitted states or their political subdivisions to employ federal-aid funds for retirement of bond issues used to construct projects on the interstate system as well as on the federal-aid primary and urban systems. The 1952 Act for the first time authorized federal funds specifically for the interstate system.

The growing inadequacy of our highways was recognized in the Act of 1954, which raised interstate system funds from $25 to $175 million and substantially increased funds for other systems. The Act also changed the formula for apportionment of interstate system money to place more emphasis on population.

Act of 1956

The Act of 1956 ranks as one of the most important in the 40-year history of federal aid to highways. It forms the backbone of the largest federal-state construction program yet undertaken.

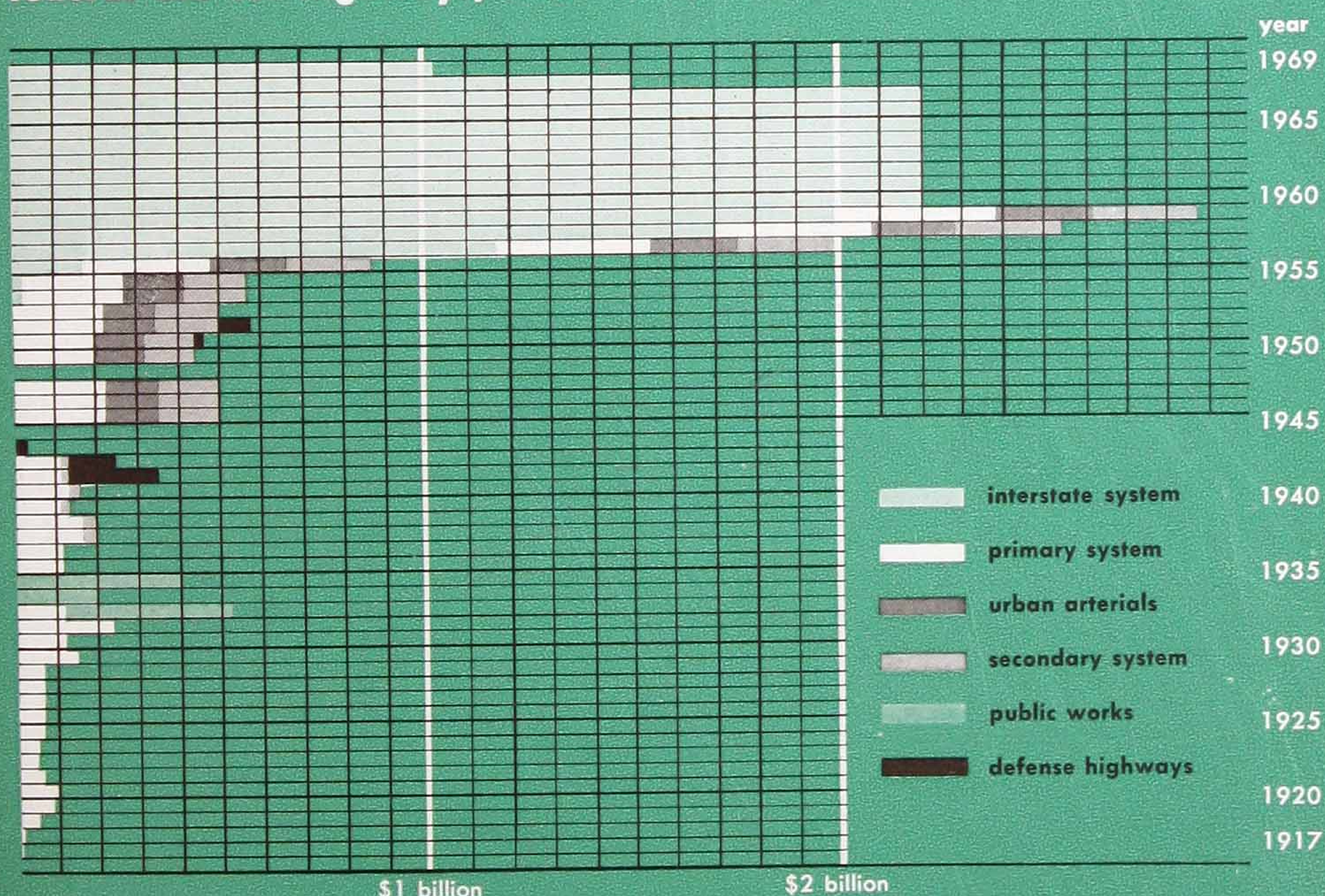
Major emphasis in the Act of 1956 is on the interstate system. The Act:

—changed the name of this heavy-duty network to the National System of Interstate and Defense Highways;

—changed the matching provisions for this system by increasing the federal share of costs to 90 per cent, with 10 per cent to be paid by the states;

—provided for a 13-year federal-state program to bring the interstate system up to acceptable standards of adequacy and authorized federal outlays of $24.8 billion over the period 1957–1969 for this purpose.

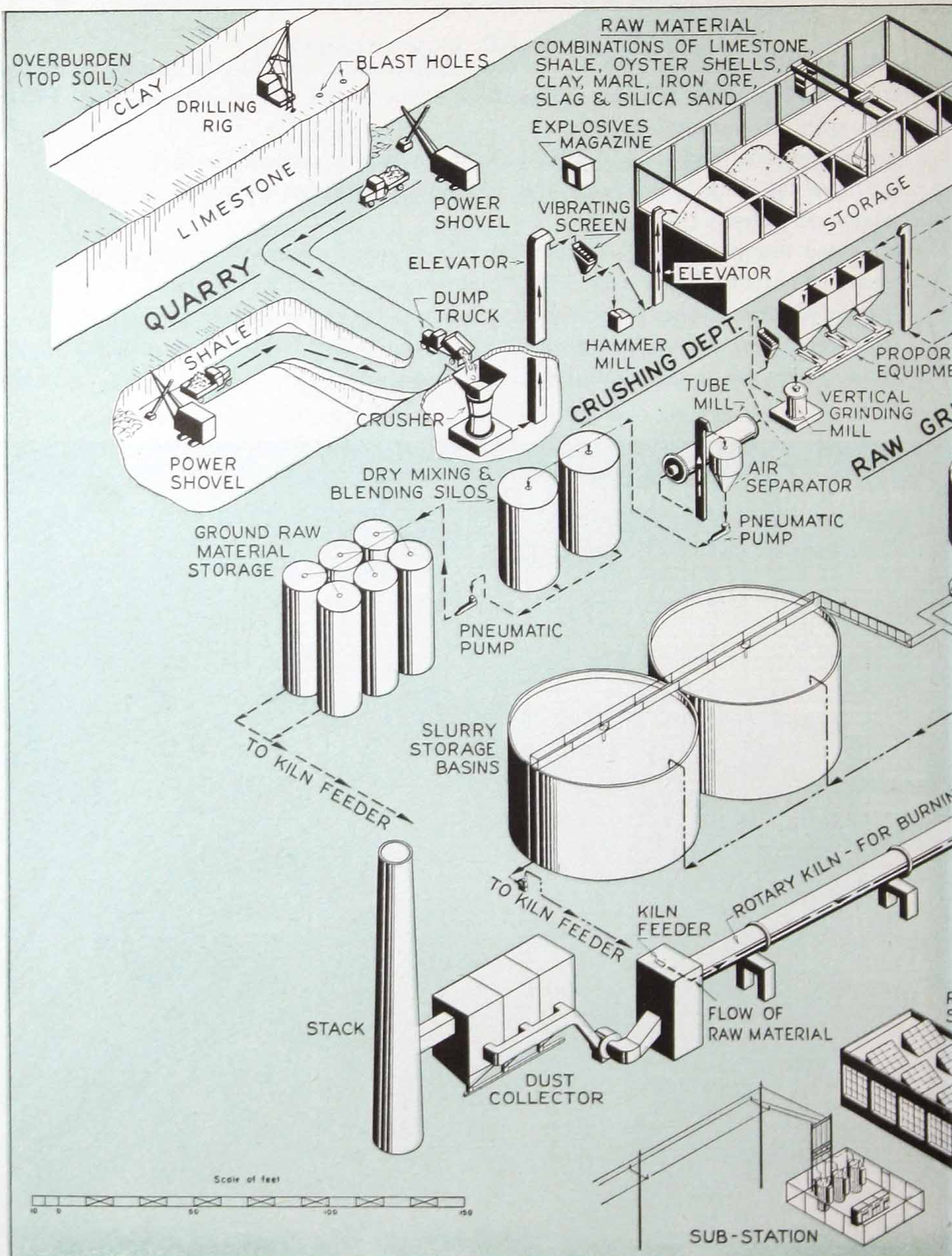
federal aid for highways, 1917–1969 authorizations for fiscal years[a]

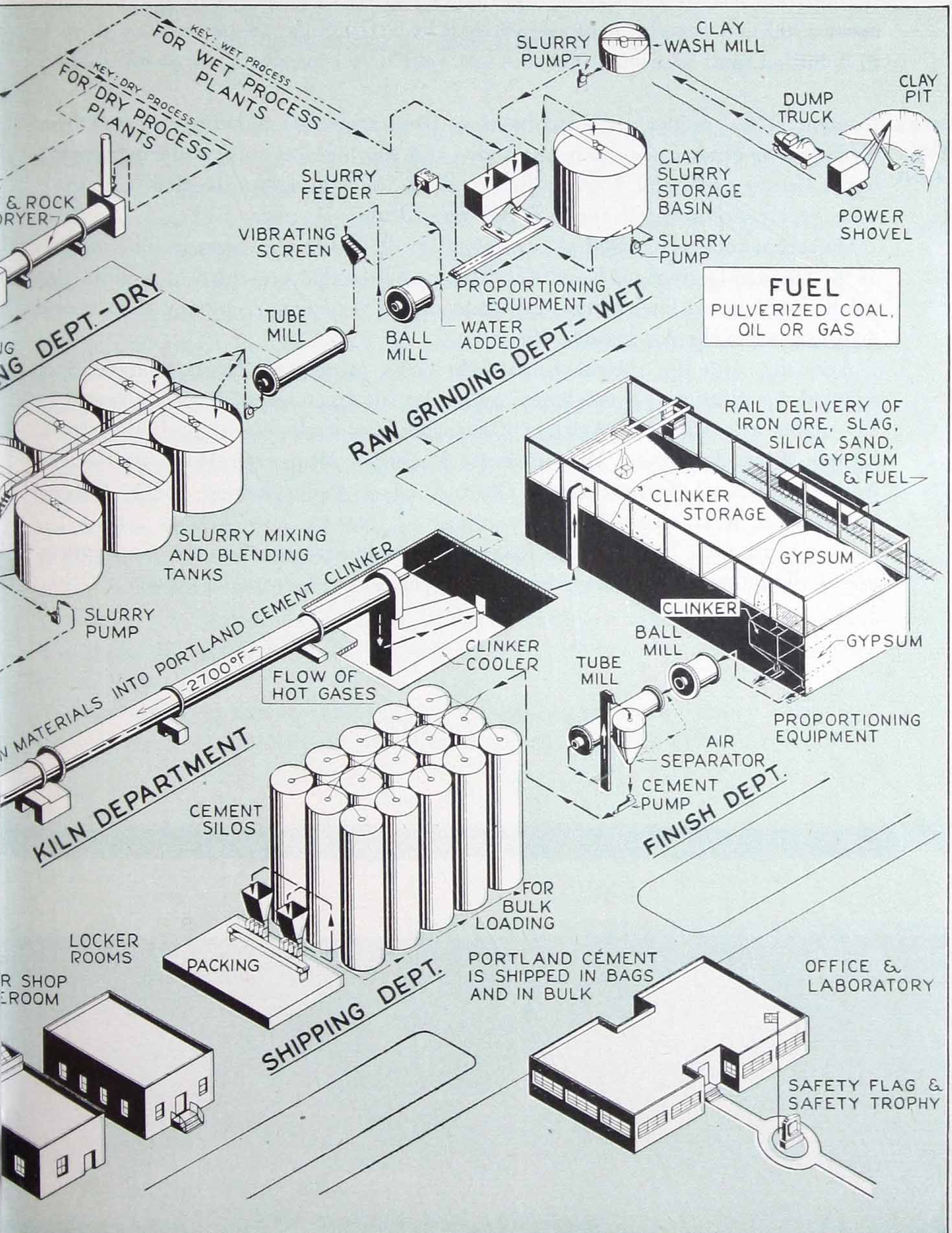


source: Bureau of Public Roads, U.S. Department of Commerce

(a) The Federal-Aid Highway Act of 1956 authorized appropriations through 1969 for the interstate system only. Appropriations for other systems were made for the normal two-year period.

isometric flow chart of the manufacture of portland cement




KEY: WET PROCESS
FOR WET PROCESS PLANTS
KEY: DRY PROCESS
FOR DRY PROCESS PLANTS
SLURRY PUMP
CLAY WASH MILL
DUMP TRUCK
CLAY PIT
SLURRY FEEDER
CLAY SLURRY STORAGE BASIN
POWER SHOVEL
& ROCK
RYER
VIBRATING SCREEN
SLURRY PUMP
PROPORTIONING EQUIPMENT
FUEL
PULVERIZED COAL, OIL OR GAS
TUBE MILL
BALL MILL
WATER ADDED
NG DEPT.-DRY
RAW GRINDING DEPT.-WET
RAIL DELIVERY OF IRON ORE, SLAG, SILICA SAND, GYPSUM & FUEL
CLINKER STORAGE
GYPSUM
SLURRY MIXING AND BLENDING TANKS
CLINKER
BALL MILL
GYPSUM
SLURRY PUMP
CLINKER COOLER
TUBE MILL
W MATERIALS INTO PORTLAND CEMENT CLINKER
2700°F
FLOW OF HOT GASES
PROPORTIONING EQUIPMENT
AIR SEPARATOR
CEMENT PUMP
KILN DEPARTMENT
CEMENT SILOS
FINISH DEPT.
FOR BULK LOADING
LOCKER ROOMS
PACKING
R SHOP
EROOM
PORTLAND CEMENT IS SHIPPED IN BAGS AND IN BULK
OFFICE & LABORATORY
SHIPPING DEPT.
SAFETY FLAG & SAFETY TROPHY

This Act also added $1 billion to the $175 million already authorized by the Act of 1954 for the interstate system in the fiscal year 1957 and increased primary and urban system funds for that year by a total of $125 million.

Interstate system funds authorized under the Act of 1956 rise to $2.2 billion in fiscal 1960 and remain at this level until fiscal 1968. In that year they drop to $1.5 billion, and in fiscal 1969, the last year of the program, to $1.025 billion.

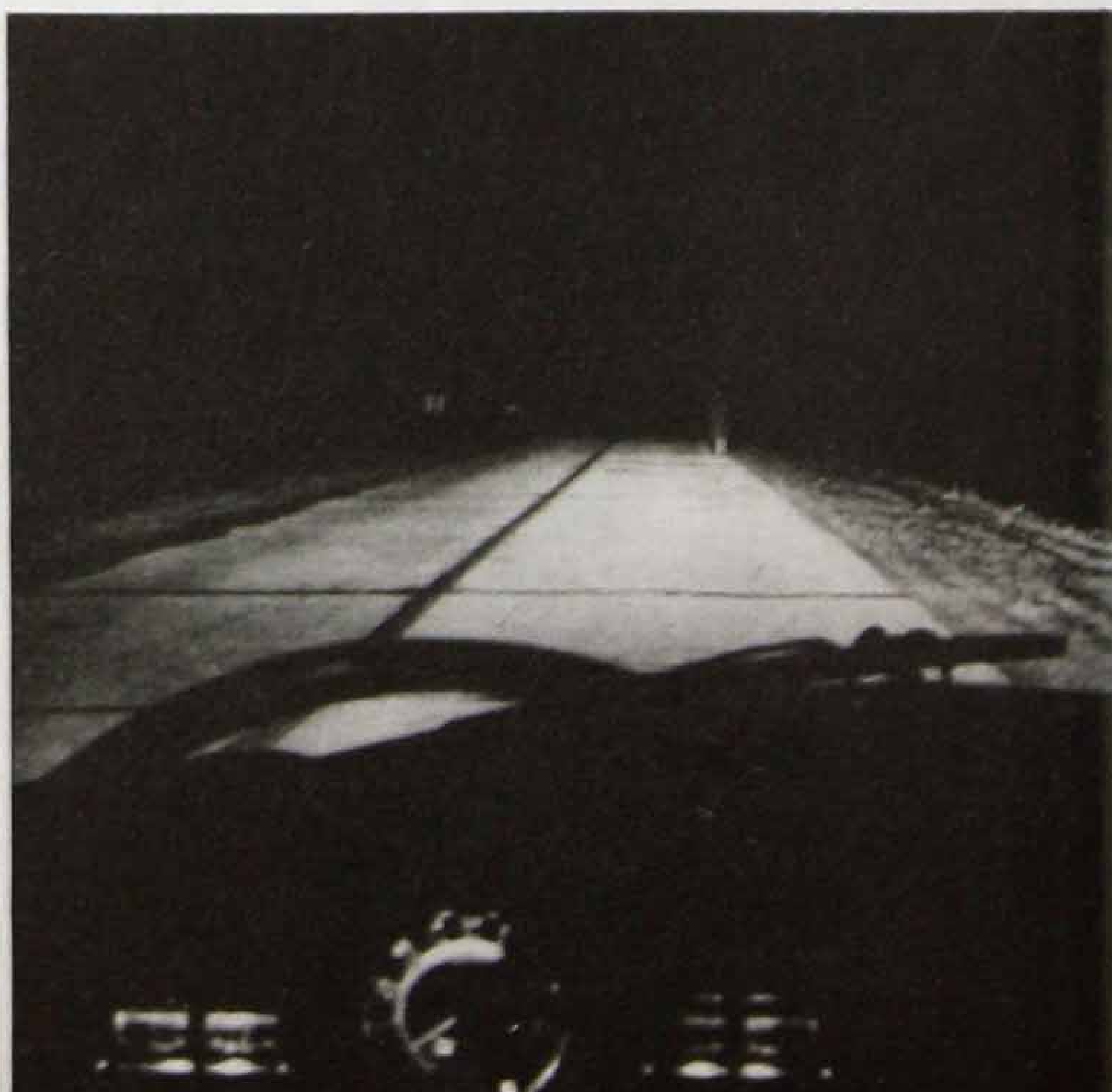
States Outlaw Diversion

In some states, money collected in taxes from motorists is being diverted from highways to other uses within the state—and the highways are suffering accordingly. Between $75 and $100 million of these funds is being diverted from highways yearly, according to the U.S. Bureau of Public Roads.

Diversion was recognized as a menace in 1934 with the passage by Congress of the Hayden-Cartwright Road Act. This provided that one-third of federal road funds could be withheld from any state that diverted more money than it was diverting when the Act became effective.

Agreeing with the Hayden-Cartwright Act's principles, 24 states have since adopted constitutional amendments outlawing all diversion of highway revenues. The states are Alabama, Arizona, California, Colorado, Georgia, Idaho, Iowa, Kansas, Kentucky, Maine, Massachusetts, Michigan, Minnesota, Missouri, Nevada, New Hampshire, North Dakota, Ohio, Oregon, Pennsylvania, South Dakota, Washington, West Virginia and Wyoming.

In addition, in Texas a constitutional amendment prohibits the nonhighway use of all motor-vehicle license fees and 75 per cent of motor-fuel taxes.



highway safety

VEHICLE accidents in the United States in 1955 caused 38,300 deaths and 1,350,000 personal injuries according to the National Safety Council. These accidents have resulted in a direct economic loss of $4.7 billion.

The number of traffic fatalities in 1955 has been exceeded only in 1941, when 39,969 people died. A study by the Automobile Manufacturers Association indicates that inadequate highways now cost U.S. motorists $1.7 billion yearly in traffic accidents that would not occur if needed road improvements were made; $1.8 billion yearly in time losses for commercial vehicles with paid drivers; $1.3 billion yearly in wasted gasoline and extra wear on brakes and tires due to traffic delays; and $500 million yearly in additional vehicle-operating costs on dirt and gravel roads that carry sufficient traffic to merit improved surfacing.

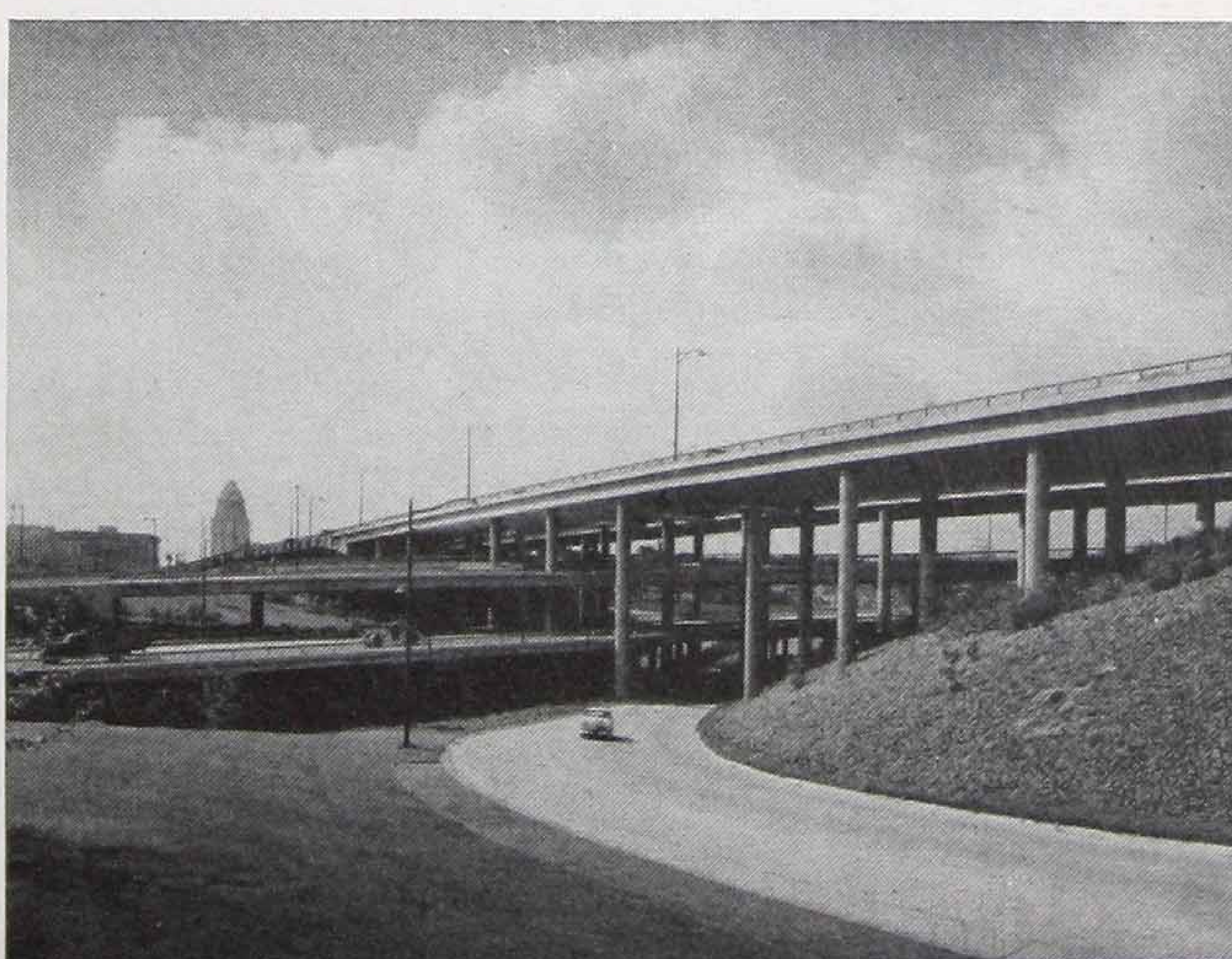
In a message to Congress on highway needs, President Eisenhower pointed to estimates by highway authorities that this cost penalty is about one cent per travel mile, or more than $5 billion a year.

Besides tightening enforcement of traffic laws and extending driver education, traffic experts are cooperating with highway authorities in an effort to reduce accidents by a careful survey of the physical defects of roads, and by the scientific application of these findings to the correction of road factors that contribute to accidents.

Notable among the various national groups organized to combat traffic accidents is the President's Highway Safety Conference, which offers a comprehen-

Left—Most fatal accidents occur at night. These photographs taken on the same night with identical camera settings and under identical conditions display graphically the greater light-reflectance and visibility of light-colored concrete pavement.

Right—Traffic is unhampered and crossing at grade is completely eliminated by this modern four-level concrete highway separation structure in downtown Los Angeles.



sive, workable approach to the safety problem. This organization has met annually since 1947 to map out yearly campaigns against America's most lethal domestic enemy—highway accidents. At the 1947 meeting, a program for action was adopted, to be based on adequate accident records, proper laws and ordinances, education, enforcement, engineering, motor-vehicle administration, public information and public support. The Conference emphasized the need to build highways as nearly accident-proof as possible as a vital step toward highway safety.

Automotive Safety Foundation

The Automotive Safety Foundation also has done much to further the cause of traffic safety. Originally set up to deal only with automotive safety, the Foundation expanded its activities during the early part of World War II to include cooperation in the conducting of publicly financed highway planning and research. Much statistical material and many valuable traffic studies have been sponsored by this organization.

The Foundation is supported jointly by motor-vehicle manufacturers, parts and accessories manufacturers, rubber-tire manufacturers, petroleum companies and the Portland Cement Association.

Another group working in the same direction is the National Safety Council, which gathers and distributes information regarding the causes of all classes of accidents and the best methods of preventing them. The gist of its findings is issued annually in its official publication, *Accident Facts*.

Accident Rating Helps

The Bureau of Public Roads is cooperating with all the states to set up a system of accident reporting that will help to determine the extent to which the physical condition of roads contributes to accidents. Some states are making progress along this line by giving ratings to accident-prone locations and then applying engineering techniques to eliminate the conditions that make the location dangerous. This procedure, engineers point out, gets quick results. With the elimination of recognized hazards at specific points, the kinds of accidents to which the danger spots contributed are not likely to be repeated.

Engineers now have the facts needed to build safe highways. One of the important reasons accident rates are still high is that not enough safe highways have been built. Limited funds have kept many dangerous highways from being transformed by good design and construction into safe ones.

For example, on comparative 43-mile sections of the Boston Post Road and the Merritt and Wilbur Cross parkways, a recent report of the Division of Highway Control of Connecticut points out that motorists on the parkways have a nearly three times better chance of avoiding fatal accidents than motorists on the Post Road. Over a nine-year period, the death rate on the parkway test section was 3.5 per 100 million vehicle-miles as compared with 9.4 on the Post Road.

The best way to achieve safety in roads is to build safety in. Concrete, because of its gritty surface texture, its low crown and its far better nighttime visibility, contributes to maximum highway safety day and night. And it stays safe longer than other types of pavements.

soil-cement

The year 1955 marked the twentieth anniversary of the first scientifically controlled soil-cement road built in the United States. This road, a $1\frac{1}{2}$-mile stretch of experimental pavement near Johnsonville, S.C., is still satisfactorily carrying traffic, which has increased far beyond the amount expected when the road was built.

Soil-cement is a tightly compacted mixture of soil or roadway material, portland cement and water, that forms a strong, durable pavement base as the cement hardens the soil. A bituminous surface is placed on the soil-cement base to complete the pavement.

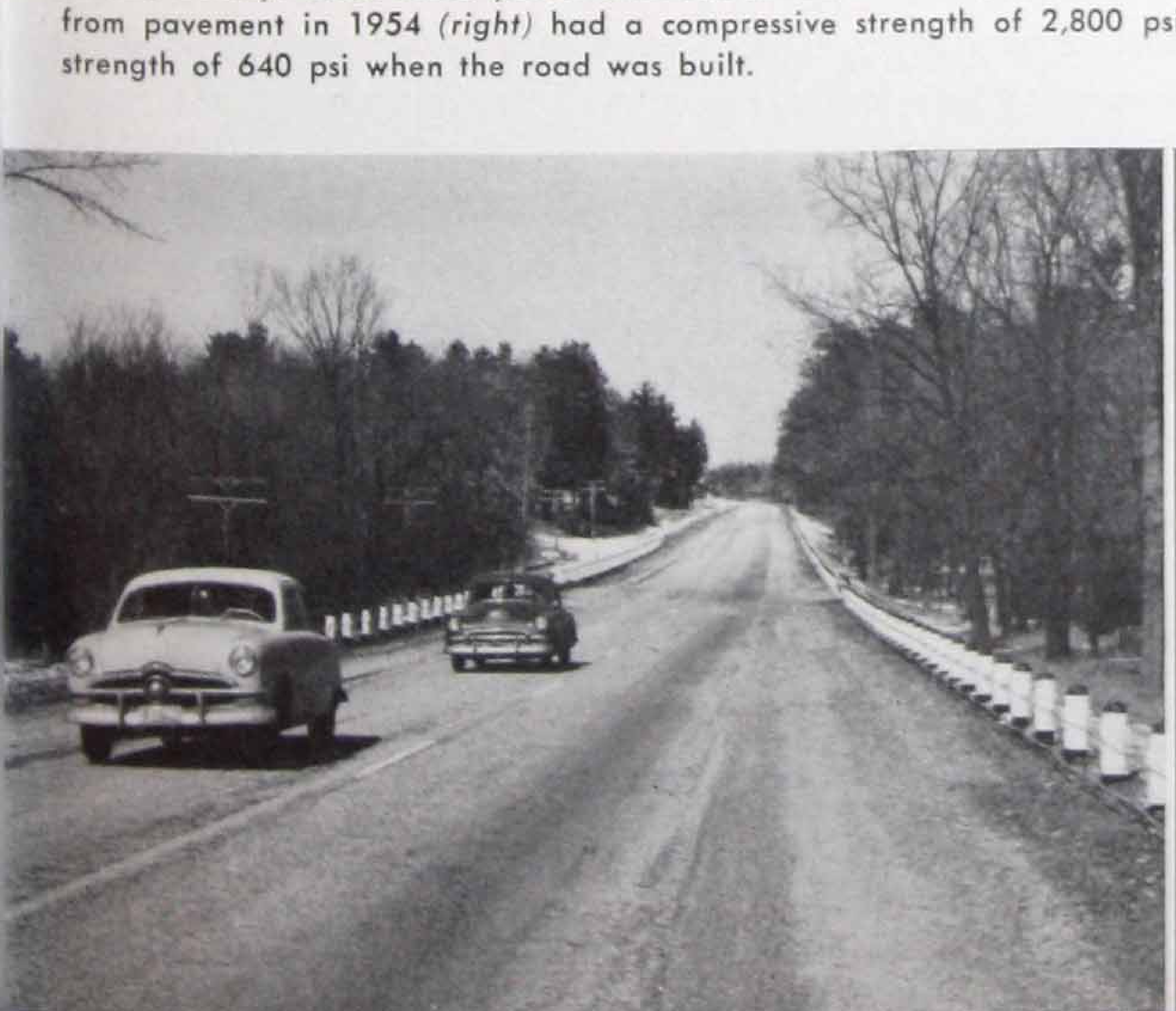
Mixing soil and portland cement together to make a pavement base was a revolutionary idea to many engineers in 1935. But it proved to be a method—long sought after—of stabilizing roadway soils to produce a truly satisfactory low-cost pavement.

Now soil-cement is widely used to pave roads, residential streets, airports and parking areas. Because of its success in these fields, its area of use has been expanded to include canal and ditch linings, dam facings, and subbases for concrete pavement.

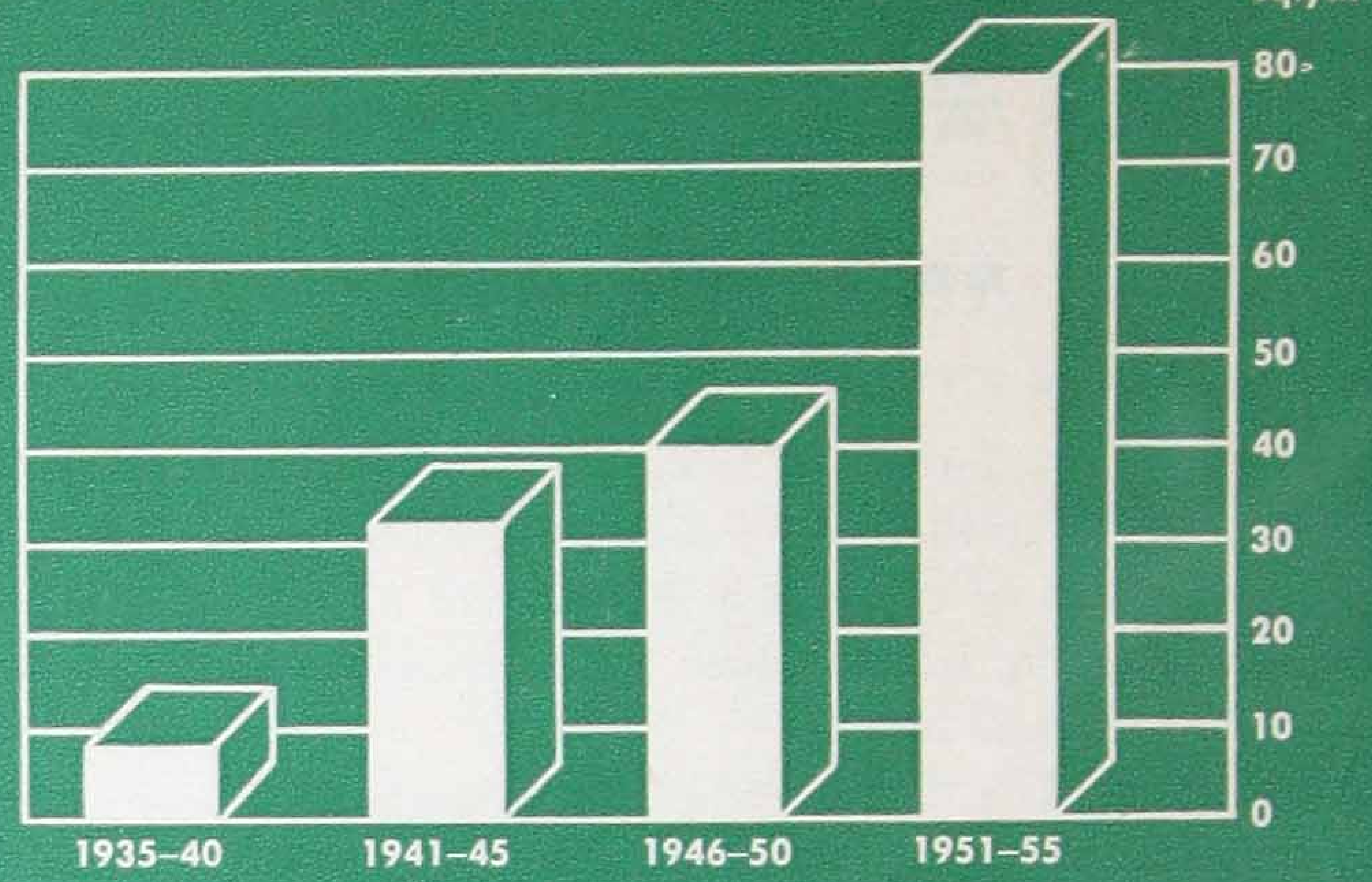
Developed by PCA Engineers

Soil-cement was developed after years of research and engineering study. Early work was done by the state highway departments of Ohio, Texas, Iowa, South Dakota, California and South Carolina. Experiments with soil-cement mixtures by the South Carolina Highway Department produced particularly encouraging

Adams County, Wis., road, paved with soil-cement in 1936, is still in excellent condition. Block cut from pavement in 1954 *(right)* had a compressive strength of 2,800 psi as compared with a 7-day strength of 640 psi when the road was built.



20-year growth of soil-cement paving awards, 1935–1955



results that led the Portland Cement Association to undertake an extensive research program, starting in 1935.

The objective of the program was to develop an adequate paving material with a cost low enough to fit the requirements of roads and streets on which the volume of traffic was too small to justify use of concrete pavement or for which available construction funds were limited.

In 1938 the PCA won the American Trade Association Executives' Award for its work in further development of soil-cement. The award is made annually to the trade association that has rendered the most outstanding service to its industry, to industry as a whole and to the public.

Properties of Soil-Cement

Soil-cement generally is built from soil on or near the paving site. Old, deteriorated granular-base materials can also be used. Only cement and water need be hauled in.

Because soil-cement is compacted tightly during construction, it does not pound down under traffic or develop soft spots or chuck holes. It is capable of bridging over localized weak subgrade areas and is highly resistant to deterioration caused by moisture and weather.

Well-known pavement-design methods used by several state highway departments require thicknesses of soil-cement that are one-third to one-half less than the required thicknesses of granular bases carrying the same traffic load over the same subgrade. This means that soil-cement is 50 to 100 per cent stronger inch for inch than other low-cost pavements.

Use of Soil-Cement

At the beginning of 1956, more than 160 million sq.yd. of soil-cement was in service in the United States, including 8,500 miles of roads and 2,700 miles of streets in some 400 cities, towns and villages. The soil-cement used in 156 air

ports—more than 23 million sq.yd.—is equivalent to nearly 2,000 miles of 20-ft. wide highway. One city, San Diego, Calif., has more than 200 miles of soil-cement streets and another, Baton Rouge, La., has more than 175 miles.

California, one of the largest users among the states, had built up to January 1956 a total of 56 million sq.yd. of soil-cement—or the equivalent of 4,700 miles of 20-ft. wide highway.

Tests Assure Quality

The success of soil-cement construction is assured when three basic requirements are satisfied. They are adequate cement content, proper moisture content and adequate compaction. These requirements are established by simple tests that have been adopted as standards by the American Society of Testing Materials, the American Association of State Highway Officials and the American Standards Association. Recently the tests have been further simplified as a result of continued research by the Portland Cement Association.

Simple to Construct

The basic steps in soil-cement construction are spreading cement, mixing and compacting. After the roadway has been shaped to grade and the soil loosened, the required amount of cement is spread. Cement and the necessary amount of water are thoroughly mixed with the soil by means of a traveling mixing machine or by rotary mixers.

The mixed material is compacted by rollers, shaped to the proper contour and again rolled to obtain a smooth finish. A bituminous material is sprayed on the soil-cement soon after finishing to seal in moisture needed for cement hydration. The pavement is then completed by the addition of a bituminous surface.

Highly efficient machinery now available for soil-cement construction has enabled an even greater reduction of its cost through mass production. Construction of a half-mile to a mile of soil-cement a day is common on average-sized projects.

Three steps of soil-cement construction are shown here. In background a mixing machine blends soil, cement and water. In right foreground, a sheepsfoot roller gives the mixture its initial compaction. Motor grader at left smooths mixture prior to further compaction.

square yards of soil-cement paving, by states completed to January 1, 1956

state	roads	streets	airports	misc.	total
Alabama	258,549	743,731	———	350,864	1,353,144
Arizona	291,290	4,430	———	22,176	317,896
Arkansas	807,898	472,116	227,499	———	1,507,513
California	41,607,018	9,572,452	2,824,462	1,824,395	55,828,327
Colorado	557,960	69,330	198,755	16,800	842,845
Connecticut . . .	1,777	13,668	86,224	10,000	111,669
Delaware	42,472	———	———	———	42,472
Dist. of Columbia .	———	5,127	———	71,939	77,066
Florida	305,141	119,388	2,022,286	361,453	2,808,268
Georgia	2,457,156	4,530,116	3,165,843	8,400	10,161,515
Idaho	451,900	72,140	———	———	524,040
Illinois	1,467,967	822,585	132,895	114,627	2,538,074
Indiana	277,850	425,105	892,579	280	1,595,814
Iowa	767,862	216,995	1,114,143	10,000	2,109,000
Kansas	1,264,931	38,944	462,076	50,500	1,816,451
Kentucky	1,286,707	26,900	74,004	106,222	1,493,833
Louisiana	10,588,841	6,515,811	573,316	10,301	17,688,269
Maine	10,574	5,700	819,999	———	836,273
Maryland	132,817	178,110	92,223	21,550	424,700
Massachusetts . .	10,000	236,435	860,174	21,300	1,127,909
Michigan	381,346	30,721	162,995	3,500	578,562
Minnesota . . .	1,541,979	112,573	694,841	1,400	2,350,793
Mississippi . . .	1,888,601	851,804	201,864	260,200	3,202,469
Missouri	1,068,979	75,174	191,130	4,000	1,339,283
Montana	———	3,000	———	———	3,000
Nebraska	1,272,465	6,295	70,395	6,000	1,355,155
Nevada	182,300	22,200	73,330	350,000	627,830
New Hampshire .	———	———	———	———	———
New Jersey . . .	457,906	518,178	202,730	59,300	1,238,114
New Mexico . .	298,815	96,570	743,100	15,950	1,154,435
New York	270,548	114,048	388,204	101,151	873,951
North Carolina . .	10,240,530	633,737	365,614	12,048	11,251,929
North Dakota . .	221,874	116,307	280,965	2,280	621,426
Ohio	1,743,122	115,762	2,100	97,070	1,958,054
Oklahoma. . . .	810,683	398,825	322,536	10,683	1,542,727
Oregon	2,444	———	———	———	2,444
Pennsylvania . .	1,459,274	27,436	192,500	———	1,679,210
Rhode Island . .	8,100	28,450	70,700	10,100	117,350
South Dakota . .	———	———	———	———	———
South Carolina . .	1,316,629	436,230	1,351,155	10,073	3,114,087
Tennessee . . .	1,889,818	362,156	135,658	39,497	2,427,129
Texas	5,818,840	2,423,284	2,814,865	362,795	11,419,784
Utah	533,910	7,700	———	54,126	595,736
Vermont	59,552	28,100	———	3,400	91,052
Virginia	2,795,130	1,324,208	27,207	157,115	4,303,660
Washington . . .	2,109,935	53,356	1,894,715	226,000	4,284,006
West Virginia . .	331,760	———	———	———	331,760
Wisconsin	521,571	394,614	13,250	9,626	939,061
Wyoming	369,700	119,300	16,000	———	505,000
Alaska	42,240	———	———	———	42,240
totals	100,226,761	32,369,111	23,762,332	4,797,121	161,155,325

concrete for airports

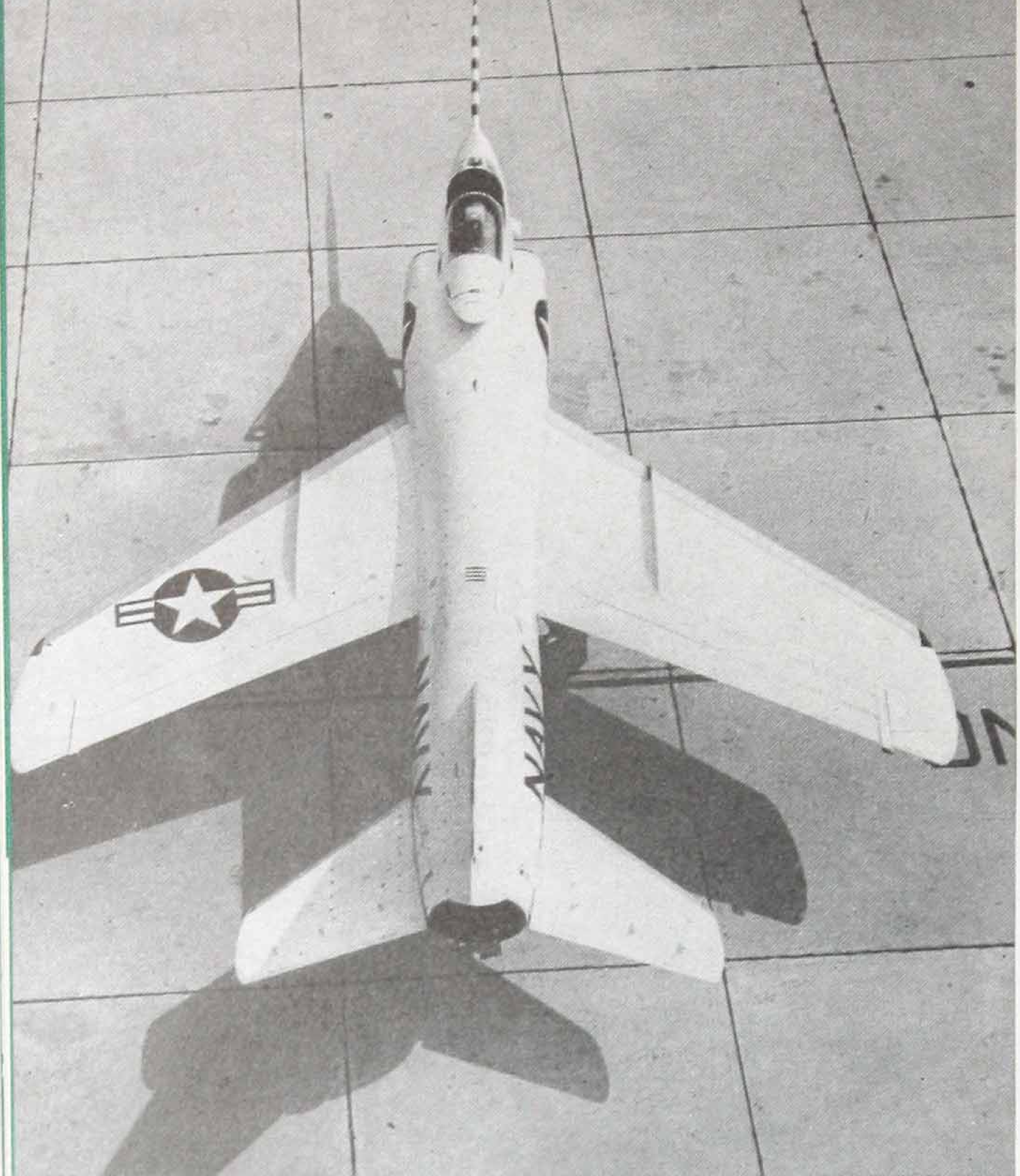
SAFE, profitable air operations require efficient ground facilities to receive, dispatch and service aircraft. The problems of providing adequate airport facilities have been materially increased since World War II by the birth of the jet age. Concrete, however, has more than kept pace with this latest major development in aviation—the use of jet planes by the military and their expected early extension into the commercial airline field. Concrete is not affected by the unburned jet fuel spilled on the pavement or by the terrific heat, blast effect or high-pressure tires characteristic of jet-plane operation. Also, concrete's freedom from loose chips and stones that "kick up" and injure passengers or aircraft becomes even more important in the case of a jet, since the presence of foreign particles in the engine may cause serious damage.

First Concrete Airport in 1927

The first concrete airport pavement in the United States was built at the Ford Airport, Dearborn, Mich., in 1927, and the first municipal airport use of concrete pavement was in Glendale, Calif., in 1929. Twenty-nine years later, from this modest beginning had grown more than 293 million sq.yd. of concrete runways, taxiways and aprons in service at some 820 civil and military airports in the United States.

The largest single runway in the world today in terms of total amount of concrete used is at Edwards Air Force Base, Muroc, Calif. Designed to handle aircraft

Concrete runways and aprons can be designed for the heaviest wheel loads of modern aircraft. Concrete also meets the challenge of varying exposure conditions.



Concrete is the only paving material that successfully withstands the heat, blast and spilled fuel of jet planes. For this reason it is widely used for military and naval airfields, and for installations at aircraft manufacturing plants, such as this one at Peconic River, N.Y. The wasp-waist plane is the F9F-9, Navy fighter designed to crash the sound barrier.

heavier than any used today, this runway is more than 15,000 ft. (or nearly three miles) in length, 300 ft. wide, and 16 to 18 in. thick.

The New York International Airport (Idlewild) is one of the world's largest and most modern civil airports. This huge new airport has seven concrete runways totaling 10 miles—and each runway is 200 ft. wide by 12 in. thick, constructed to accommodate aircraft up to 300,000 lb. Translated into terms of highway pavement, the concrete used in the runways alone at Idlewild would be sufficient to build a highway 22 ft. wide and 8 in. thick from Philadelphia to Washington, D.C., a distance of about 140 miles.

McConnell Air Force Base in Wichita, Kan., has the greatest area of concrete pavement of any airport in the United States—3,750,000 sq.yd. Also over the two million mark in square yards of concrete pavement are Barksdale Air Force Base, Shreveport, La.; Carswell Air Force Base, Fort Worth, Texas; Edwards Air Force Base, Muroc, Calif.; Forbes Air Force Base, Topeka, Kan.; Kelly Field, San Antonio, Texas; Lake Charles Air Force Base, Lake Charles, La.; Larson Air Force Base, Moses Lake, Wash.; Lincoln Air Force Base, Lincoln, Neb.; Lockbourne Air Force Base, Lockbourne, Ohio; Patuxent River Naval Air Station, Cedar Point, Md.; Smoky Hill Air Force Base, Salina, Kan.; Tulsa Municipal Airport, Tulsa, Okla.; and Wright-Patterson Air Force Base, Dayton, Ohio.

Concrete Contributes to Safety

There are many reasons for the rapid growth and popularity of the use of concrete in airport installations. Chief among them is concrete's contribution to safety. In any airport the most vital ground installation is the runway. From the time the wheels of a landing aircraft first touch the runway until the ship again becomes airborne, the runways must insure safe, skid-free landings, easy take-offs and strength to sustain tremendous loads.

Safety in landing is largely dependent on good runway visibility. The light color of concrete runways makes them easily visible to the pilot, especially at night, and is an important element in effective, economical lighting. Concrete runways are also skid-resistant, and their low crown reduces the tendency of an aircraft to veer toward the runway edge.

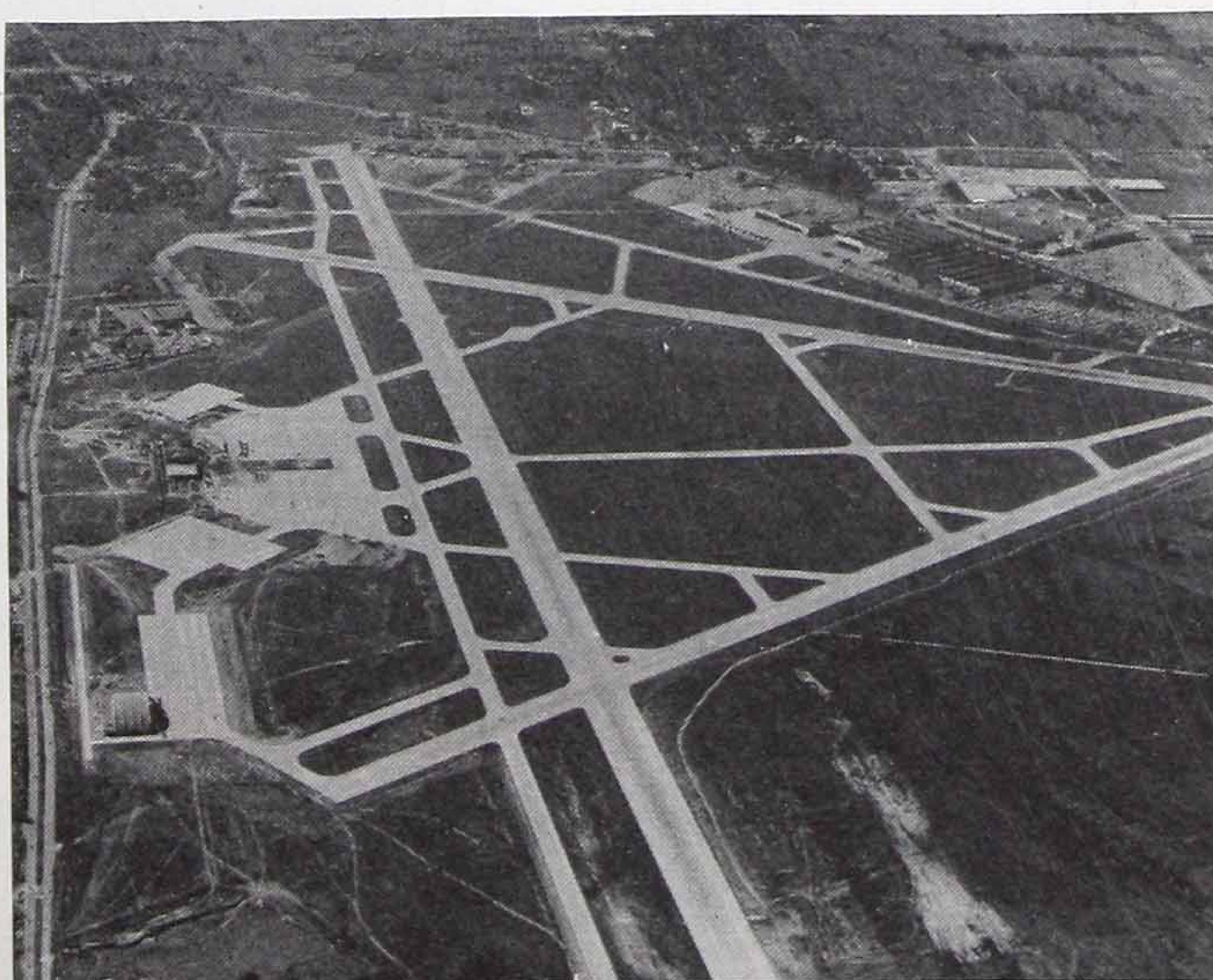
Runway strips, taxiways and aprons must sustain gross plane weights of more than 500,000 lb. The high compressive and beam strength of concrete makes it physically and economically desirable on subgrades of either low or high bearing power.

Concrete pavements for aprons, taxiways and runway ends can be designed to carry the heaviest planes moving slowly or standing still with engines "revving up" prior to take-off.

Federal Aid Given

The Federal Airport Act of 1946 allocated $500 million to the states to be disbursed over a seven-year period. Under the terms of this Act, the federal government will provide financial aid up to 50 per cent of the cost of civilian airport construction. This fund is administered by the Civil Aeronautics Authority—three-fourths of it in accordance with a formula prescribed in the Federal Airport Act, the other quarter at the discretion of CAA officials. This federal aid applies only in the initial construction of an airport; it is stipulated that maintenance is the obligation of the sponsoring municipality or organization.

The 1946 Act was scheduled to expire on June 20, 1953. However, in September 1950, Congress extended the time limit for completion of the Federal Airport Act program for an additional five years, moving the expiration date to 1958.



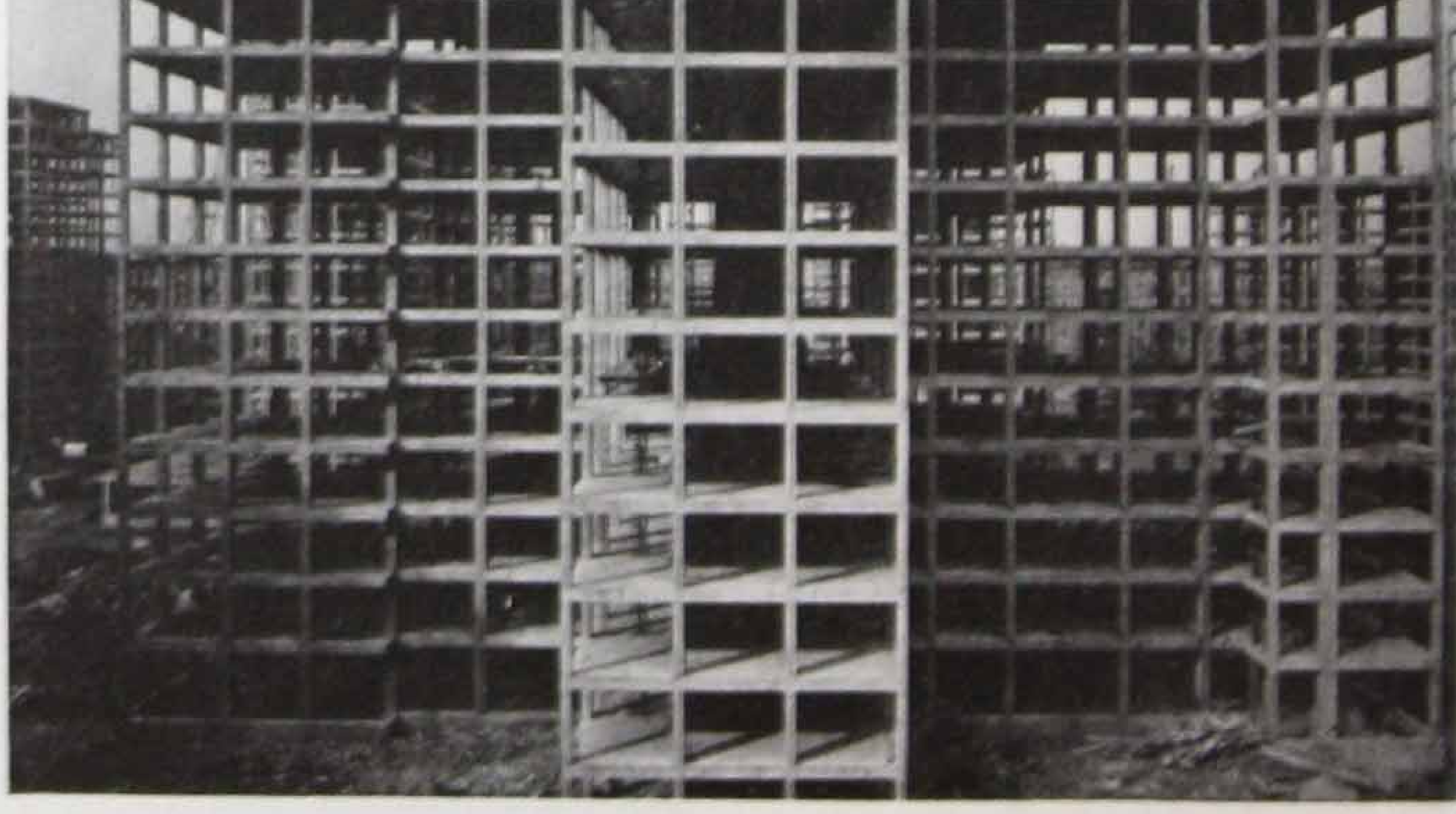
Unretouched aerial photograph of Lambert Field, St. Louis, Mo., shows the high visibility of concrete—an important factor in safe landings, particularly in inclement weather. —Photograph by Lloyd Spainhower.

reinforced concrete

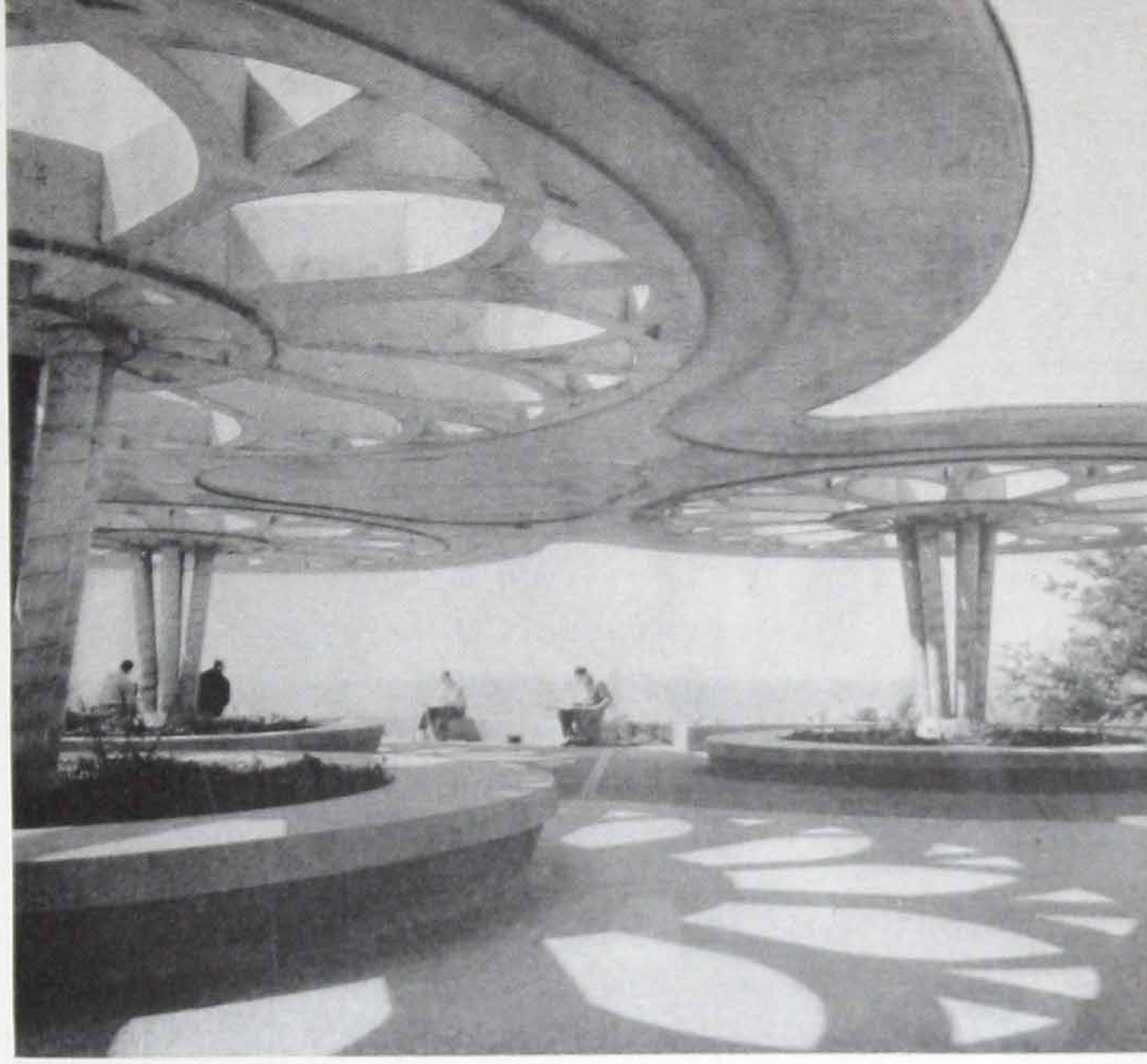
CONCRETE is stronger in compression than in tension. When concrete structural members such as floor beams must resist large tensile stresses, steel, which is high in tensile strength or resistance to pulling apart, is embedded in concrete in the form of bars or mesh. This supplements the strength of the concrete, forming reinforced concrete structural members capable of sustaining heavy loads. Thus engineers can design concrete floors and other parts of a structure so they will carry the anticipated loads with safety and economy.

Reinforced concrete was first used about 1850, when Joseph Monier, a French gardener, built thin-walled concrete tubs, tanks and garden pots with metal reinforcement. Monier was granted his first patent on a system of reinforced concrete construction in 1857, although not until 1880 was his system put into general use.

Two other Frenchmen, Joseph Louis Lambot and François Coignet, were pioneers in the development of reinforced concrete construction. Lambot is reputed to have built a reinforced concrete boat, which he exhibited at the Paris Exposition in 1855. In the same year, Coignet announced his principles for reinforced concrete construction, suggesting that beams, arches and pipe could be satisfactorily made in this way.



Reinforced concrete building frames are widely used in structures that are to house large numbers of people, where strength and firesafety are all-important. This 14-story building in New York is part of an apartment project built by the New York Housing Authority.



Concrete can be molded into almost any shape or form. Its strength and versatility permit the architect and engineer to build grace and beauty into usually commonplace structures. These three 30-ft. wide concrete canopies form a park shelter in Cincinnati, Ohio.

Among the most important early reinforced concrete patents was one issued in 1877 to Thaddeus Hyatt, American lawyer and inventor. The theories advanced in his patent application were based in part on laboratory tests of reinforced concrete beams. The principles derived from these beam tests strongly influenced the development of reinforced concrete construction.

The first important practical applications of reinforced concrete for building construction in America were in structures designed on the Pacific Coast by E. L. Ransome during the last quarter of the nineteenth century. He first used old wire cable and hoop iron for reinforcement in small buildings, and the success of his early efforts led to the use of reinforced concrete in many large structures on the West Coast—one of the most notable being the Leland Stanford, Jr., Museum at Palo Alto, Calif., which came through the 1906 earthquake with only minor structural damage.

The first reinforced concrete bridge in the United States was built in Prospect Park, N.Y., in 1871. According to most authorities, the first wholly reinforced concrete building in this country was the W. E. Ward house, built in New York in 1875. It was not until the turn of the twentieth century, however, that this type of construction became common. The first reinforced concrete skyscraper in the United States was the 16-story Ingalls office building, constructed in Cincinnati in 1902 and 1903.

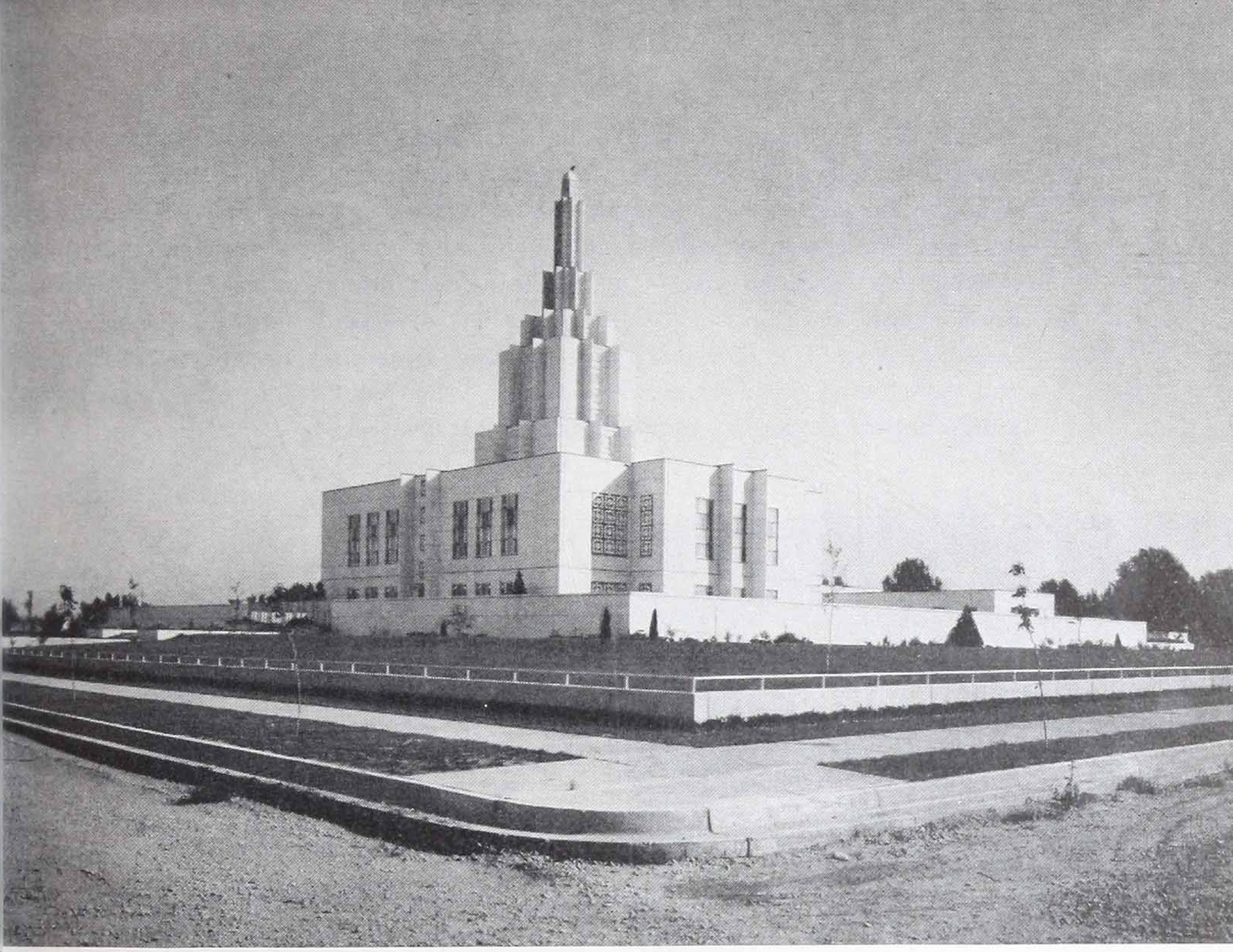
Since that time, experience and research have resulted in steady improvement of reinforced concrete design and construction practice. Today, reinforced concrete is accepted and widely used not only for building construction but for a variety of purposes ranging from a simple fence post to the largest and most complicated engineering projects.

architectural concrete

ARCHITECTURAL concrete is reinforced concrete used for both the ornamentation and the structural parts of a building. However, a building with a structural frame of some other material is classed as architectural concrete if the enclosing walls and features that determine its architectural appearance are exposed concrete.

Concrete was recognized early as a rugged material of great durability and strength. For many years, consequently, it was employed almost entirely for structural purposes while its beauty potential remained unrecognized and undeveloped. Its emergence during the last three decades as an architectural material has coincided with the appearance of the contemporary or modern style of architecture. As the architectural styles rendered in concrete and illustrated on these pages will affirm, concrete is a versatile medium for expression.

Factory-produced cast-stone wall panels were used for the Kenmore Apartments in Washington, D.C. White precast 4x6-ft. panels were used to give horizontal emphasis to the façade, while smaller grey panels were used between windows. The precast panels served as exterior forms for the cast-in-place lightweight concrete walls.



For the Temple of the Church of Jesus Christ of Latter-Day Saints in Idaho Falls, Idaho, white portland cement was used for the architectural concrete to obtain extra whiteness.

First Used in West

Architectural concrete in the United States was first used extensively on the Pacific Coast. Several conditions peculiar to this section were responsible for development of the new material. Western builders were anxious to abandon the conventional eastern forms, and concrete offered an adaptable material for experimentation. Another cogent factor of local importance was the high earthquake resistance of reinforced concrete. From the West Coast, architectural concrete has spread throughout the country.

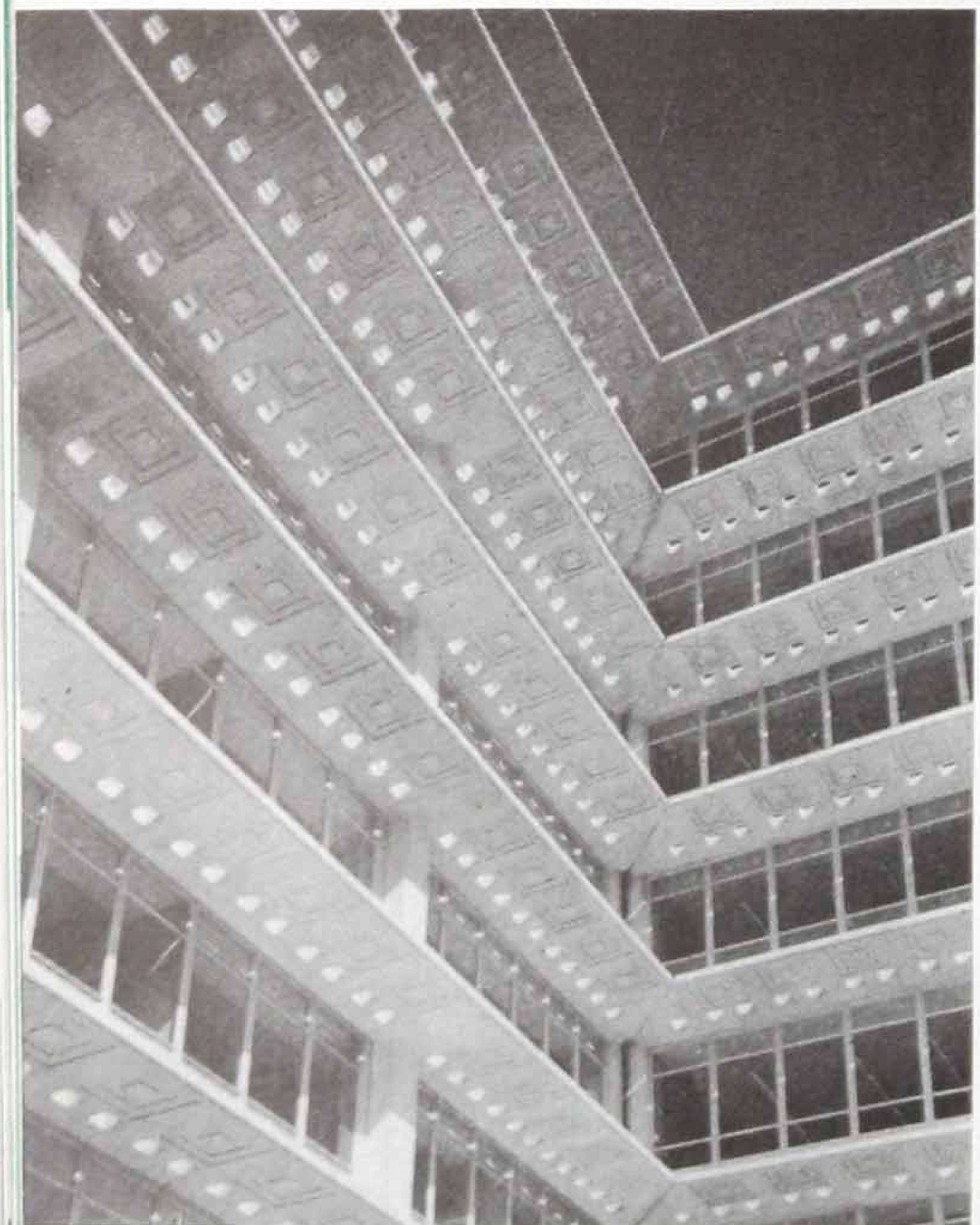
An important property of concrete is its workability when first placed, a quality that permits its being molded into practically any shape or form an architect may conceive. Exterior and interior wall surfaces may vary widely depending on the material used for the forms or form linings.

Concrete's workability is particularly valuable in the execution of ornamental details. All elements of the concrete building—ornamental as well as structural—may be cast integrally in one construction operation at a substantial saving in building cost. Fluting, rustications, incised or relief patterns and other ornamental devices are executed easily and economically in concrete. Molds may be re-used many times to carry out a motif.

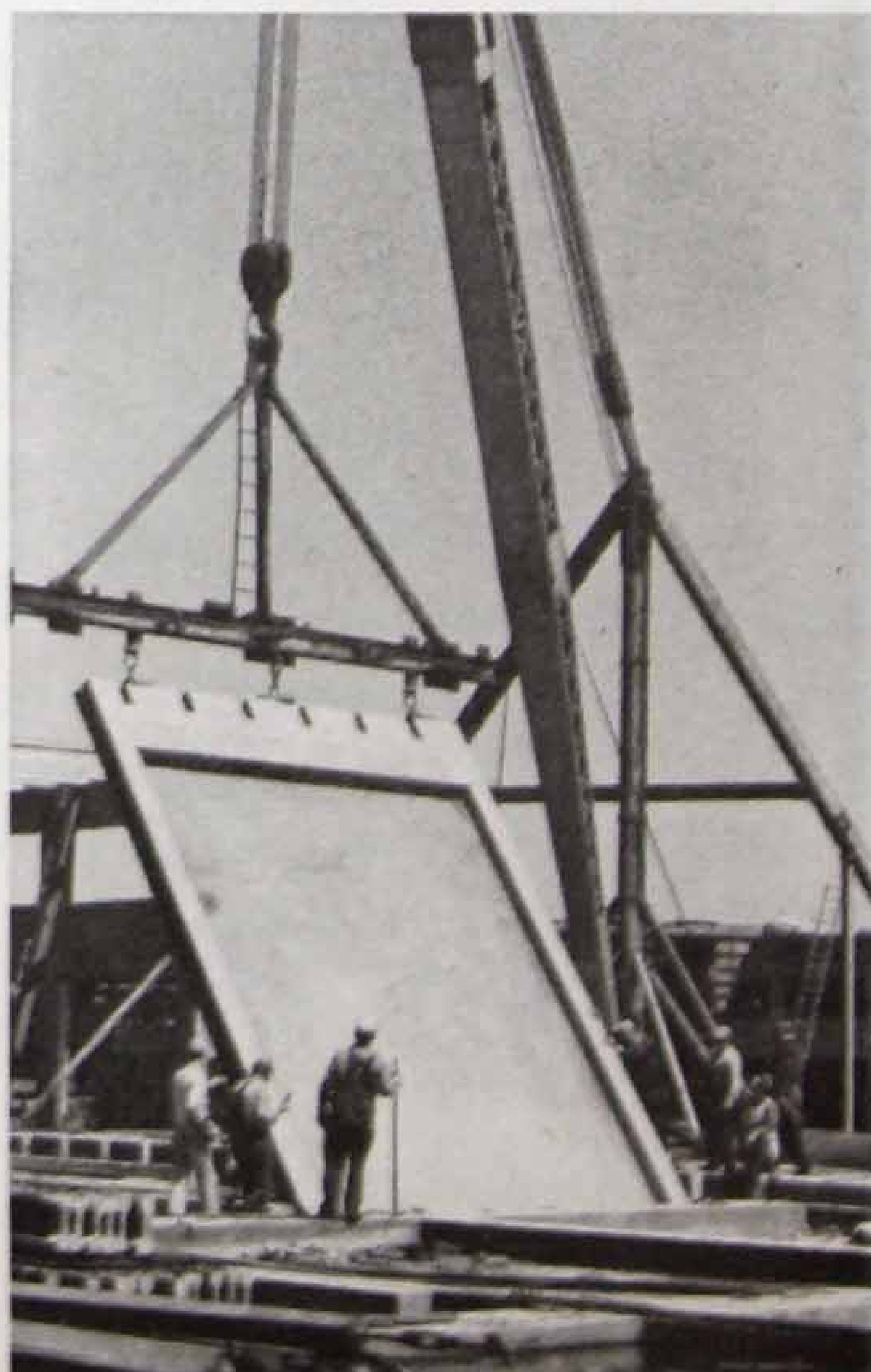
Use of Color Growing

During the next decade an increasingly widespread use of color in architectural concrete may be expected. A broad range of paints, stains and pigments are available now for adding color to concrete to enhance its attractiveness. Recent developments in the use of colored aggregates and bond-transfer techniques make possible the maximum use of the natural beauty of the aggregates, producing architectural concrete in an additional variety of striking finishes.

Architectural concrete stands today between the satisfying progress of the past and the exciting possibilities of the future. Whatever the future of architectural design may be, concrete can give it form and substance.



In the new Medical Center in Little Rock, Ark., floor slabs were cantilevered to form functional exterior canopies that provide shade from the summer sun. Designs were cast into the canopies' undersides for architectural effect.



tilt-up

THE use of tilt-up construction for reinforced concrete structures gained increasing favor after World War II by helping the construction industry to provide badly needed buildings in the face of labor and material shortages.

Tilt-up is a fast, economical method of building individually designed reinforced concrete structures by casting the walls on a horizontal base and then tilting them into position. The tilt-up method is economical because it requires minimum use of forms and makes efficient use of modern mechanical equipment.

Simplicity is the keynote of the procedure in constructing tilt-up buildings. The foundation wall and footings are placed in the usual manner. The reinforced concrete floor slab is then laid and coated or covered to prevent the wall panels from bonding to it.

Next, simple wood or steel edge forms are prepared and placed in position on the concrete floor, which is used as a base for casting wall panels in a horizontal position.

Before the wall section is cast, reinforcing steel, vapor seal, insulation, door and window frames, electric conduits and outlet boxes—as required—are placed in position.

The concrete wall panel is then cast, usually adjacent to its final position. When the concrete has hardened, a lifting device is attached to the wall section and the completed wall is tilted to a vertical position in a few minutes with power or hand-operated equipment.

The walls are fastened together at the corners or between panels with cast-in-place concrete columns. Metal clips, clamps or welded reinforcing rods may also be used to fasten precast units together. Any conventional roof system may be used. The whole operation is speedy and economical, and has proved to be eminently satisfactory.

Mass Production Projects

Tilt-up is especially advantageous for one-story structures but has also been successfully used for multistory buildings. With the use of tilt-up, the project can be readily laid out for mass production. The larger the project, the greater the possibility for effecting economies.

Tilt-up offers a variety of architectural effects and exterior surface treatments. Panel lengths and heights are equally adaptable to standardized and individually designed buildings. Tilt-up retains all the desirable features of concrete construction, including firesafety, attractiveness of design and low maintenance cost.

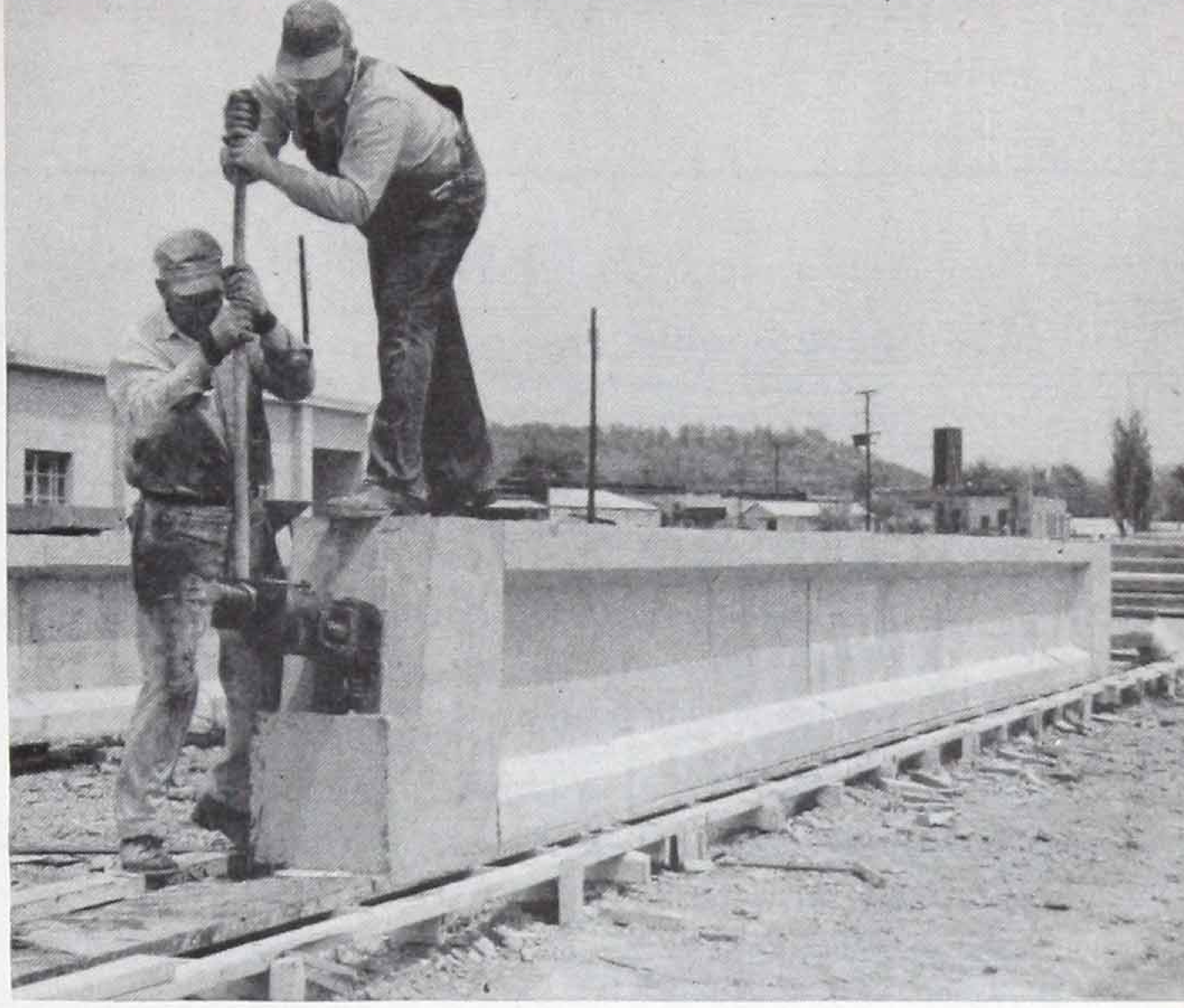
In tilt-up construction, concrete wall panels or sections are cast in a flat position. After hardening and curing they are raised to a vertical position by a hoisting rig. Cast-in-place columns are used to tie the panels securely together.

prestressed concrete

In conventional reinforced concrete (page 68), the high tensile strength of steel is combined with concrete's great compressive strength to form a structural material that is strong in both compression and tension. As excellent as this combination of ordinary steel and concrete has proved to be, it does not take full advantage of the higher concrete strengths now readily obtained. Physically, in many cases, it is impossible to provide enough steel to develop a tensile strength equal to the concrete compressive strength. This is overcome by introducing a compressive force on the concrete by a process called prestressing.

Prestressing breaks down previous limitations on the spans and loads for which a concrete structure can be economically designed. It permits the building of concrete bridges, roofs, floors and structural members of longer unsupported spans than ever before. It enables architects and engineers to design and build lighter, shallower concrete structures, where these qualities are needed, without sacrificing strength. And it permits the construction of concrete pipe and tanks to resist even greater internal pressures.

Seven prestressed concrete girders were used to provide unobstructed floor space of about 14,000 sq.ft. in the Greensboro, N.C., high school gymnasium. Vertical prestressing cables tie columns and girders together. At the time of construction, these were the longest prestressed concrete girders used for roof construction in the United States.



The principle of prestressing is demonstrated here. A hydraulic jack is used to stretch the reinforcing steel and place the concrete in the beam in compression.

Tensile Stresses Neutralized

The basic idea of prestressed concrete is to eliminate or greatly reduce the tensile or tearing-apart stresses to which certain portions of bridges and buildings and the walls of tanks and pipe are subjected. This is done by stretching the reinforcing steel so as to superimpose compressive stresses in the concrete.

The strengthening effect of compression is similar to the "squeeze" put on a horizontal row of books when they are transferred from one place to another. A row of books has a form similar to that of a beam, although the volumes are not bound together. When sufficient pressure is applied to the two end books, compressive stresses are induced throughout the row. The books may be lifted and carried horizontally, even though the center volumes are unsupported.

Two Methods

These strengthening compressive stresses are induced in prestressed concrete in one of two major ways: by the *pre*tensioning or by the *post*tensioning of the steel reinforcement.

In the pretensioning process, the steel is stretched *before* the concrete is placed or has hardened. After the concrete has hardened around the tensioned reinforcement, the jacks or stretching forces are released. Then, as the steel seeks to regain its original length, the tensile stresses are translated into compressive stresses in the concrete by means of the bond between the concrete and steel.

In posttensioning, the steel is stretched *after* the concrete has hardened, and is fastened externally by means of anchors or other gripping devices. In this process, the steel is tensioned against the concrete so that any "pull" exerted on the reinforcement results in a corresponding compressive "push" against the concrete. The greater the tension on the steel, the greater the compression in the concrete.

Because they can withstand and maintain a large amount of tensile stress, high-strength steel wires are nearly always employed in prestressing concrete—but some alloy steel rods may be used also.

do you know that . . .

During the peak of construction activity on the Grant Park Underground Parking Garage in Chicago, 3,591 cu.ft. of ready-mixed concrete was delivered and placed per hour—enough to build 224 ft. of concrete pavement 24 ft. wide and 8 in. thick?

Concrete floor slabs, weighing slightly more than 700 tons and measuring 80x195 ft., were cast one on top of another and lifted on 36 supporting columns to form the floors of a multistory building in San Antonio, Texas?

Limestone is mined as deep as 1,500 ft. underground and brought to the surface for cement manufacture?

Concrete has an important role in one of Hollywood's most expensive productions? Approximately 20,000 cu.ft. of concrete was placed for the parting of the Red Sea sequence of Cecil B. DeMille's film, *The Ten Commandments.*

First Patent Issued in United States

Although prestressed concrete is not a new idea, only about 1940 did it become recognized and developed as an important and practical type of construction.

The first patent on prestressed concrete was issued in 1888 to P. H. Jackson of San Francisco, and in following years several other patents were granted in this country. But while some of the first steps were taken in America, the initiative soon went to Europe, where the development of prestressing was taken up by engineers in France, Belgium and Germany. A major hurdle was cleared about 1928 when Eugene Freyssinet, a prominent French engineer, found that compressive stresses could best be induced in the concrete by means of high-strength steel wires. In the last decade and a half, development work abroad has been spurred by the necessity for rebuilding—in the face of a scarcity of construction materials—many bridges and structures damaged or destroyed in World War II. It was in western Europe and in England that prestressed concrete developed into full maturity and became an important type of construction.

Its success, increased use and growing application in foreign countries have been responsible for a "rediscovery" of the material in the United States, where in the past few years notable strides forward have been made. Significant among these was the start of construction in late 1949 of the Walnut Lane Bridge in Fairmount Park, Philadelphia. This structure, with a 160-ft. center span and two 74-ft. side spans, was the first prestressed concrete bridge to be started in this country. It was completed early in 1951.

After work was begun on the Walnut Lane Bridge, a second, smaller prestressed concrete bridge was built and opened to traffic in Madison County, Tenn. This bridge, officially dedicated in October 1950, was the first prestressed concrete bridge to be completed in the United States. Since then more than 225,000 ft. of prestressed concrete bridges has been built in this country.

Both as an adjunct to reinforced concrete and as a promising construction medium, prestressed concrete has many potentialities for the future. It is to be expected that important new contributions will be added to the already well-established procedures as its use increases in this country.

concrete bridges

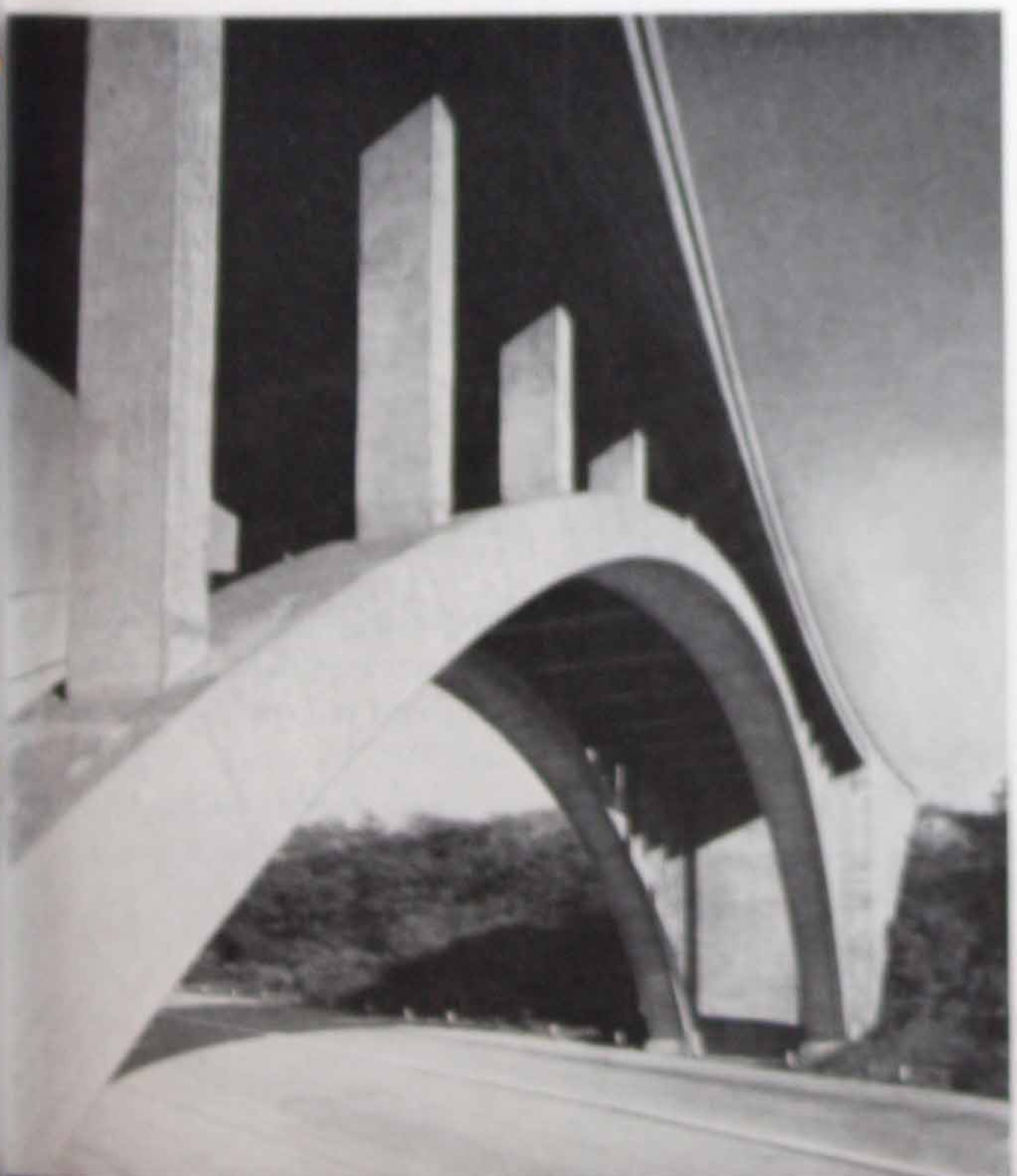
OF ALL man-made structures in the world today, few are as artistically satisfying and as inherently functional as the concrete bridge—which spans broad rivers, wide ravines and deep canyons with grace and symmetry.

Four Major Types

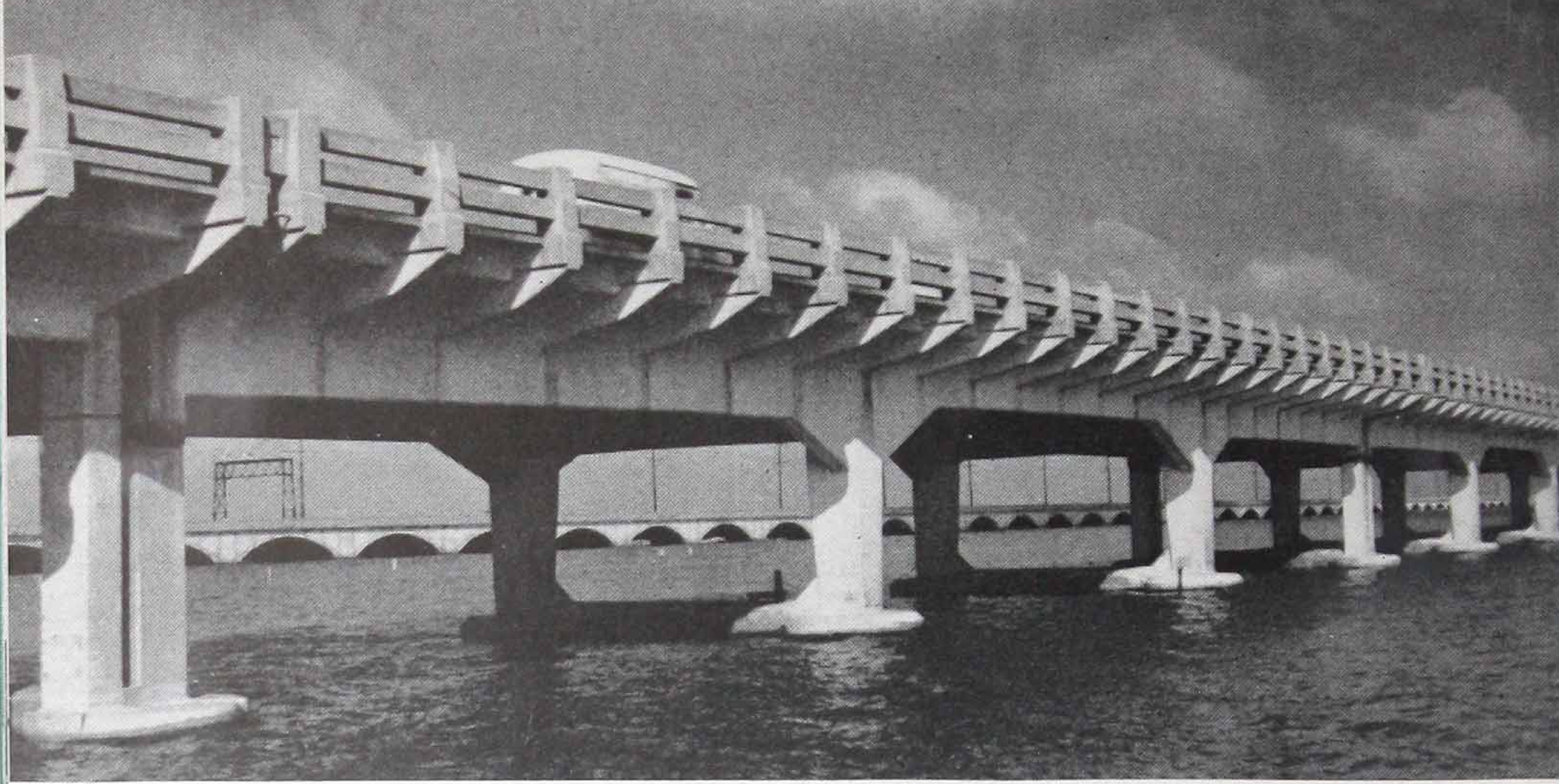
In general, there are four major types of reinforced concrete bridges: rigid frame, slab, girder and arch. Any of these designs may consist of a single span or of several spans, the latter being referred to as multiple-span bridges.

By far the most widely used type of reinforced concrete bridge today is the girder type. More spectacular, however, are the long-span arch bridges. In general, most of the large concrete arch bridges in the United States are of the multiple-span variety. In Europe, however, there are several outstanding arch bridges of single span.

A notable example of the latter is Sweden's Sandö Bridge with its 866-ft. single span, completed in 1943 under the direction of the Swedish Highway Board. This bridge, carrying a 34-ft. roadway, set a new world's record for reinforced concrete span length.



This reinforced concrete single-span arch bridge carries two 12-ft. lanes and two 5-ft. sidewalks over the Penn-Lincoln Parkway in Pittsburgh, Pa. The bridge is 251 ft. long and rises to 40 ft. above the roadway.



Reinforced concrete multispan vehicular causeway *(foreground)* is 1½ miles long and connects Galveston, Texas, with the mainland. In background is multiple-arch railway bridge of equal length.

Much smaller but almost as significant was the first reinforced concrete bridge built in the United States. Constructed at Golden Gate Park, San Francisco, in 1889, the modest little arch had a 20-ft. span with a rough-stone finish.

This country's first large-scale multiple-span concrete bridge was the Connecticut Avenue Bridge, built in Washington, D.C., just 17 years later. Its overall length is 1,341 ft.

Pioneer among single-span concrete bridges in the United States was Jack's Run Bridge, Pittsburgh, Pa., constructed in 1924; the bridge span is 320 ft.

Great Concrete Bridge Decade

Completion in 1931 of the George Westinghouse Bridge, East Pittsburgh, Pa.—which includes the longest reinforced concrete arch in the United States today, a 460-ft. span—marked the start of the greatest decade of concrete bridge construction in the nation's history.

The period 1931 through 1940 saw the completion of at least five major single- and multiple-span reinforced concrete bridges, in addition to thousands of smaller concrete bridge structures.

One of the best examples of the rigid-frame type of concrete bridge, the Aliso Street Bridge in Los Angeles, was built in 1943. Here the reinforced concrete rigid frame has a span of 222 ft.

A year later, one of the first important continuous-girder bridges in the United States was constructed to span the Chattahoochee River near Atlanta, Ga. Completed in 1944, it has 90-ft. span lengths. Of more recent and unusual design for this type is the Niles Canyon (Calif.) Bridge built in 1948. Its single columns carry a hollow concrete box girder, which in turn supports a curved bridge deck 26 ft. wide. The bridge is 1,000 ft. long, with more than half its length on a curve of 750-ft. radius. Spans are 81 ft. long.

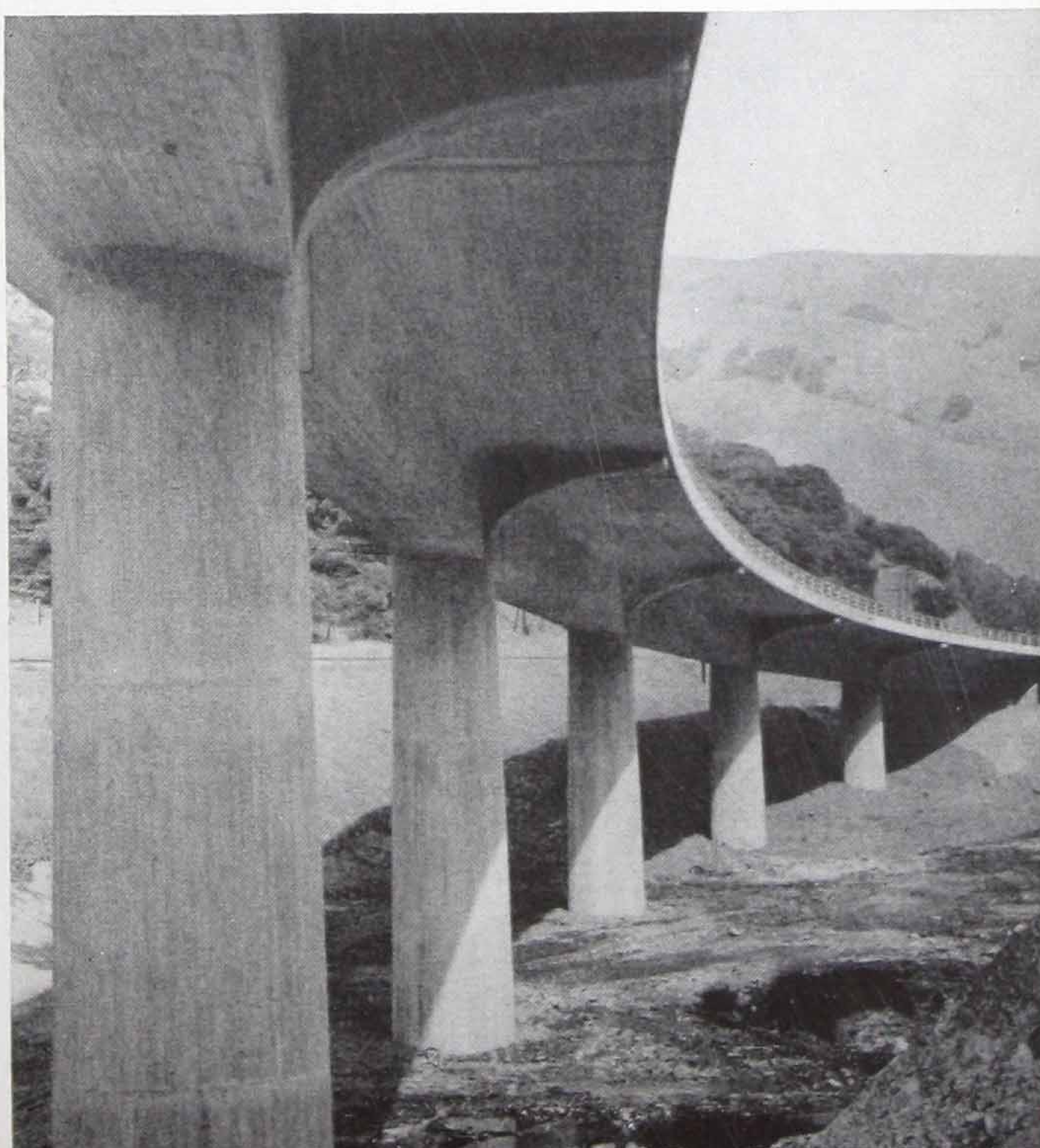
Aside from the four major concrete bridge types, there are two concrete bridges in the United States that merit special mention. The first is the Lake Washington Floating Bridge, in Seattle, Wash., which is, in effect, a stationary "raft" floating on the surface of Lake Washington. Its four-lane roadway is supported on concrete boats or pontoons. Its length of 1.3 miles makes it one of the largest floating structures in the world. The second, located near Philadelphia, is the Walnut Lane Bridge, the first prestressed concrete bridge to be put under construction in the United States.

These are only a few of the major or representative-of-type bridges in the United States. In addition, there are hundreds of smaller concrete bridges in every state of the Union and in every Canadian province.

New Bridges Needed

Many of the existing bridge structures on the nation's highway system were built for the narrow road widths and light traffic volumes and loads of several decades ago. Some of these old structures are so inadequate in strength, width or overhead clearance as to form bottlenecks in the normal flow of commercial traffic. Others present actual barriers to the emergency movement of military vehicles and equipment. The improvement and replacement of these structures, and the elimination of dangerous railroad grade crossings and highway intersections are among the most serious problems facing road officials.

Figures compiled by the Bureau of Public Roads in a report for Congress show that at the start of 1955 there was a need for the construction or improvement of 304,600 bridges on all roads and streets, at a cost of $21,600,000,000.



Graceful concrete bridge of center-pedestal type spans Alameda Creek in Niles Canyon, Calif.

railway uses of concrete

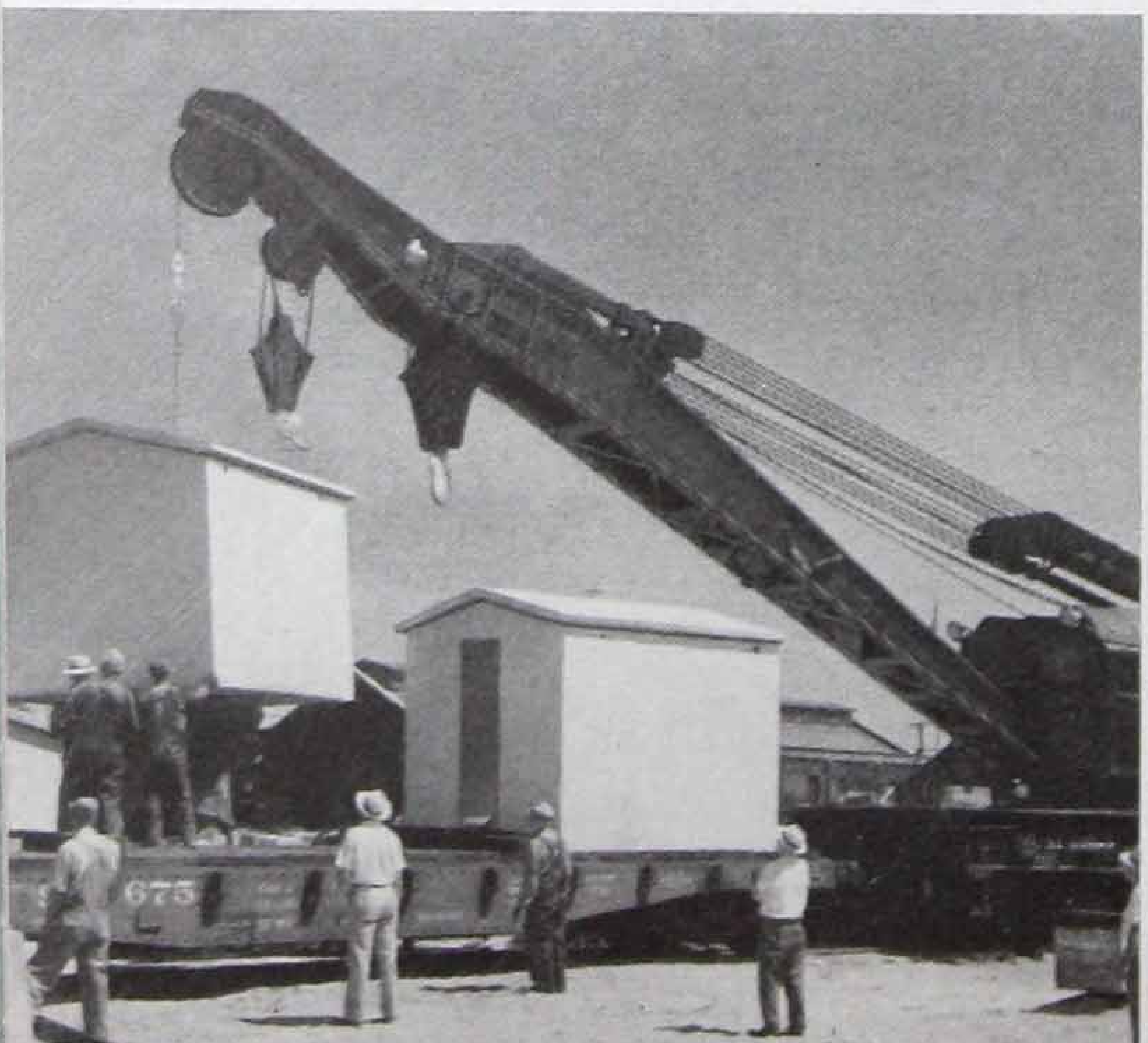
For more than half a century, American railways have used concrete in more diversified ways, possibly, than has any other industry. More than 160 uses have been counted, ranging from relatively small projects such as mile posts to large bridges, long trestles and monumental buildings. As loads increase, railroad engineers are using concrete more and more for construction and replacement projects to reduce annual maintenance charges.

Among the essential structures of any railroad are its depots, freighthouses, bridges, control towers and motive-power maintenance and fueling facilities. In all of these, concrete plays a vital role. For example, 65,000 cu.yd. of concrete went into the construction of the Los Angeles Union Passenger Terminal, which covers 45 acres. The huge concrete Santa Fe freighthouse in the same city is 815 ft. long and 60 ft. wide, and can accommodate 64 cars simultaneously.

Many Uses Go Unnoticed

But there are also many extensive railway uses of cement and concrete that remain virtually unnoticed by the public. To cite several examples, concrete is used under water in huge piers and trestles and under ground in long tunnels and culverts. Cement grout, a mixture of portland cement, sand and water (see page 106), is forced into the ground underneath track to eliminate troublesome water pockets and soft spots; it thus provides the traveling public with fast, smooth-riding railway transportation.

Left—These precast concrete signal houses illustrate one way in which railroads are using concrete to reduce on-the-site construction and maintenance. *Right*—The Pennsylvania Railroad's new freighthouse in Philadelphia was designed in concrete for firesafety and to give long service under severe traffic conditions at low maintenance cost.



Piers Keyed into Rock

In one unusual project, concrete bridge piers are keyed into solid rock as deep as 123 ft. below the water level of the Colorado River to allow trains of the Santa Fe Railway to cross a bridge between Arizona and California at a speed of 100 miles an hour in safety and comfort.

Precast reinforced concrete piles, deck slabs and bents are among the fast-growing railway uses of concrete. Louisville and Nashville Railroad trains approach a bridge spanning the Ohio River at Henderson, Ky., over a concrete trestle almost 2¼ miles in length, 20 ft. above ground, and containing 629 spans. The deck of this trestle bridge is constructed of more than 1,250 precast reinforced concrete slabs supported on precast concrete piles 24 in. in diameter. Two 20-ton slabs are placed side by side to form the deck.

Units Precast near Project

In a typical railway trestle construction project, deck slabs and piles are frequently precast at a yard near the scene of operations and cured there; then they are picked up by a crane, placed on flatcars and transported to a stockpile or directly to the site.

By means of efficient organization and the use of precast concrete units, railroads have minimized the time required for replacing old trestles and building new ones and have lowered both maintenance and replacement costs. Since most of the structural units needed for the job are preconstructed, traffic interruption is held down; on small jobs there is little or no traffic delay.

Concrete Reduces Upkeep

Concrete track support, subballast slabs and cement grouting are other important railroad uses of cement and concrete. All have grown from experimental work carried on by the American Railway Engineering Association (through the Association of American Railroads), by individual railroad companies and by the Portland Cement Association—and all have helped to reduce maintenance costs and improve riding conditions.

In Chicago's Union Station, for example, concrete track support increased the life of track 40 per cent and cut routine track maintenance 80 per cent over a 17-year period. Today 860,000 sq.ft. of concrete track support is used in its yards and under train sheds, and good track has been maintained with little trouble under conditions that would otherwise have made operation difficult and costly.

In 1952, railway companies spent approximately $1,510 million in maintenance of way and structures, the tenth consecutive year in which total expenditure for maintenance has exceeded the billion mark. Since American railroads must maintain more than 248,000 miles of track, the lowering of maintenance and replacement costs is a matter of prime importance. Concrete, because of its low annual cost, is playing an important role in this economy program.

Many Other Uses

Concrete engine terminals, station platforms, crossing slabs, ore bins, turntable walls, work pits, retaining walls, river-bank revetments and numerous other concrete structures are being constantly and increasingly used by railroads to improve service and expedite operations.

concrete shell roofs

SEVERAL types of structures such as gymnasiums, aircraft hangars and certain industrial and commercial buildings require large amounts of clear floor space and high ceilings. To provide this unobstructed area, the roofs span long distances without the support of interior columns and without large below-ceiling beams or trusses that materially reduce the usable height between roof and floor.

These requirements are successfully met by shell roofs, which can be described as thin concrete slabs curved in either one or two directions. The tremendous carrying capacity imparted to these slabs by even a slight amount of curvature is well attested by many examples in nature, such as the shell of an egg.

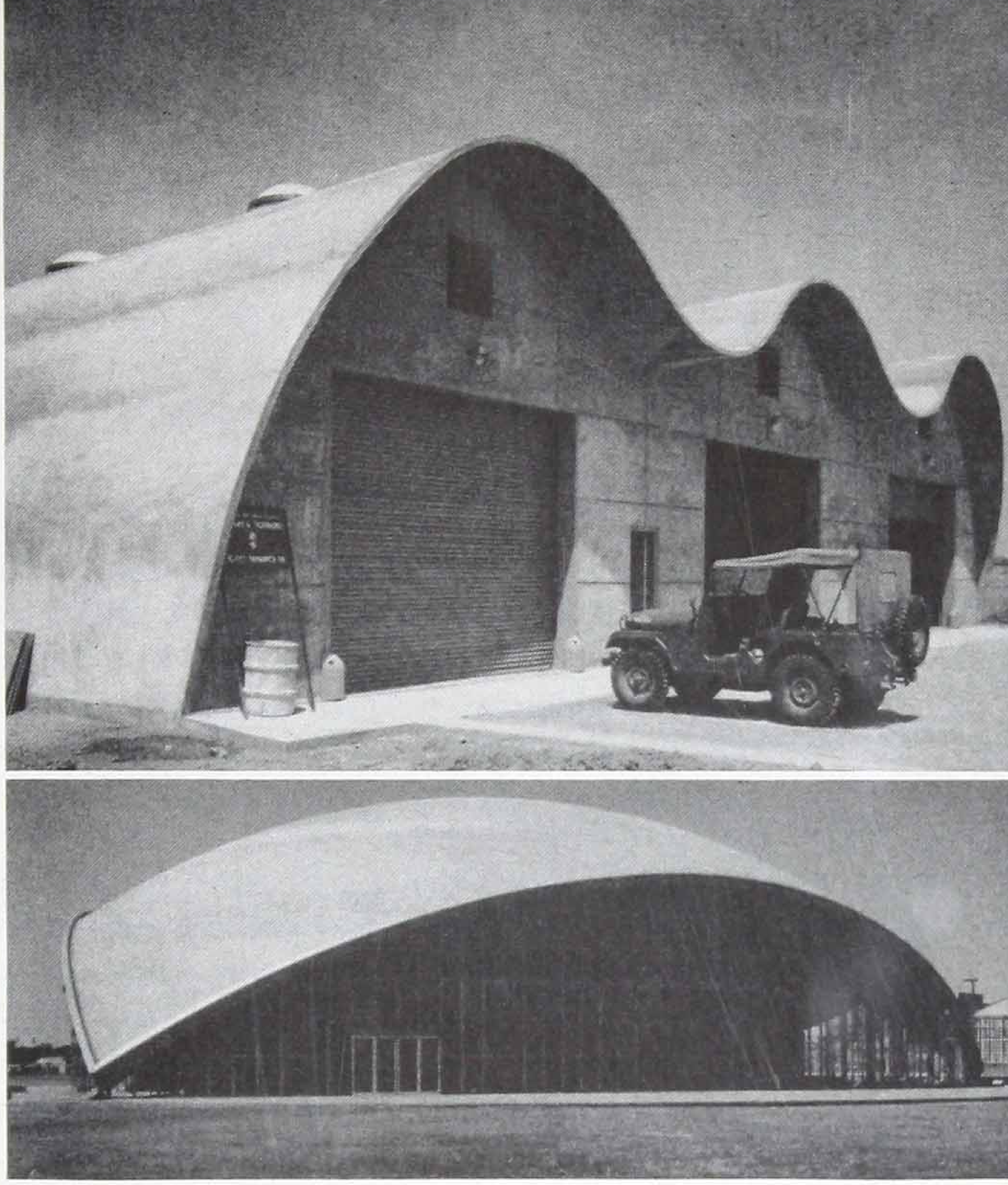
Although the principle of shell action is as old as nature itself, its application to reinforced concrete is relatively new, dating back only some 30 years to developments started in Germany. In the United States, concrete shell roof construction is even newer, and it was not until World War II that it received general recognition.

Principles of Strength

A concrete shell roof may be either barrel or dome shaped. Both of these two major types are three-dimensional, and it is this fact plus the strength of the reinforced concrete that is responsible for the great resistance of shell roofs to exterior forces and loads.

The strength of a concrete shell dome is demonstrated by a table tennis ball, which has exceptional strength and load-carrying capacity compared with the thinness of its shell. Even when the ball is cut in half, a great portion of this strength is still maintained in the "domes" that result. But if the shell area of one of these domes were flattened, it would support only a fraction of the load concentration it is capable of supporting in its spherical, three-dimensional shape. This is because in a dome every portion of the shell where a load may be placed is elastically supported by the surrounding portions of the shell, and these surrounding portions supply tensile and compressive forces to resist the load. A load concentration applied to a flat surface, however, is resisted only by bending forces, with the consequence that the induced stresses are proportionately more intense.

The principle of strength in an arched concrete shell roof can be demonstrated with a playing card. If a playing card is held in a flat position by slight clamping pressure of the fingers along one edge, it will bend deeply or collapse under the weight of a half-dollar placed on it. But if the card is curved upwards into an arch and held in this curve by pressure of the fingers, it will support the half-dollar and additional coins as well. This can be partly explained by the fact that the



The flexibility of design afforded by concrete shell roof construction is illustrated by *(top)* the undulating 3-in. thick barrel-type roof of a garage at the Lawton, Okla., National Guard Armory; *(bottom)* the triangular-shaped dome of the auditorium at Massachusetts Institute of Technology—one-eighth of a sphere covering a half-acre.

weight is resisted by thrusts acting downward over the curve formed by the shell and outward against the fingers maintaining and supporting the curve.

A reinforced concrete shell roof behaves in like manner. Curved ribs or stiffening members are placed at intervals along the entire length of the shell. These stiffening members support and maintain the curved shell, and consequently supply the reactions necessary to resist the loads placed on the shell. Because of the stiffening ribs, the shell structure acts lengthwise essentially as a beam.

Because load stresses are so well distributed, concrete shell roofs are capable of safely spanning long distances without support with a low ratio of dead weight to span. Even exceptionally large structures require only a relatively thin shell. An excellent example is provided by twin hangars built at the Chicago Midway Airport for American Airlines. Each of these hangars has a floor area of 45,000 sq.ft. covered by a concrete shell roof with a clear span of 257 ft. and a clear ceiling height at midspan of 60 ft. Yet the shell of each roof is at most points only 3½ in. thick.

The practicality and economy of shell roofs led to their ever-increasing use in Europe and South America. Because of this gain in popularity, many architects and engineers in this country are looking with keen interest to developments in shell structures, and it is not unlikely that the trend toward this type of construction abroad will be more than duplicated here.

CONCRETE masonry is being used for constructing many of the homes in today's big home-building market. The outstanding durability of concrete block gives the home-owner maximum protection from such destructive forces as storms, termites and fire. In addition, concrete block requires little repair or maintenance. There are almost as many variations in concrete houses as there are architects who design them, but generally they can be classified under two main construction types: concrete masonry or reinforced concrete.

Concrete Masonry Homes

Concrete masonry homes are constructed with units made in factories, delivered to the building site and laid into the walls by masons. Concrete masonry units, which are generally produced with hollow cores, are made of various types of aggregates, such as sand and gravel, crushed stone, slag and many other materials (see page 98). Some units are heavy and some are light in weight, depending on the kind of aggregates used in the concrete mixture.

Concrete masonry house walls are usually built of 8-in. thick units, although sometimes two walls are built of 4-in. units with an air space between. (For modular design, see page 98.)

Concrete masonry walls lend themselves readily to almost any type of insulation —valuable not only in saving winter fuel but in keeping the home cool in summer as well. All of the commonly used methods for insulating walls in various sections of the country are readily adaptable to concrete masonry.

A variety of interesting wall treatments may be produced in concrete masonry. Surfaces may be painted in any desired color with portland cement paint or other suitable paints, or they may be left unpainted. Portland cement paint is sold in dry powder form and then mixed with water before being applied. It serves not only as a decorative finish but also as weatherproofing on exterior walls. Stucco may be applied to achieve whatever special surface texture will best suit the architectural style of the house. Concrete masonry units of different sizes may be laid together in a wall to form patterns traditional in stone work—for example, random ashlar or coursed ashlar.

Unusual effects may also be created with special treatment of mortar joints. One popular wall treatment can be produced by smoothing off the vertical joints flush with the wall and tooling the horizontal joints; this gives an effect of long horizontal lines. Concrete masonry units are also widely used as backup for brick and stone facings.

Reinforced Concrete Houses

Among the variations in the construction of reinforced concrete walls, three types are most frequently applied to dwellings. One type is a solid wall, 4 to 8 in. thick according to special requirements, with lath and plaster or other insulation applied to the interior surface. A second type, known as a hollow double or "cavity" wall, consists of two 4-in. walls with a 2-in. air space between them. In a third type, the interior side is ribbed so that air spaces are formed between the plaster and the outside wall.

There are also a number of different methods of constructing reinforced concrete houses with wall sections precast in a factory and erected at the site. Another economical method of building reinforced concrete houses—the tilt-up method —is described on page 73.

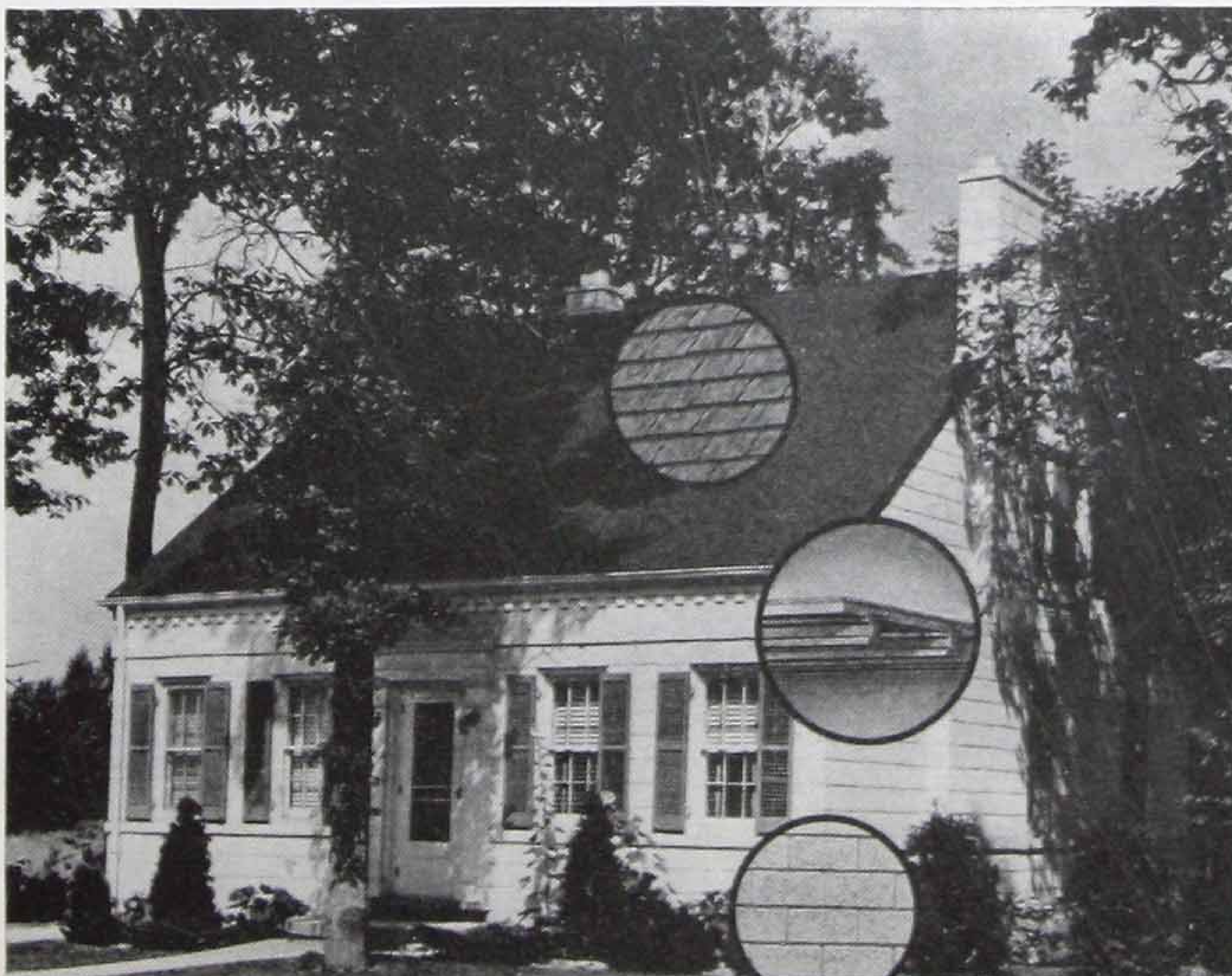
Concrete Floors

Along with improvements in methods of building concrete house walls have come labor-saving developments and refinements in constructing concrete subfloors for dwellings. Whatever type of concrete house floor is built, it is generally classed as a subfloor and is covered with carpet, hardwood strip or parquet flooring, cork or rubber tile, linoleum or terrazzo. In some instances, however, concrete floors are merely painted or waxed.

One of the most widely used methods of building these floors is with precast reinforced concrete joists. Architects often specify that concrete joists be left exposed on the underside to produce a beamed ceiling. Although these joists are commonly used with a cast-in-place concrete floor, precast concrete floor slabs may also be placed on them.

Another popular type of concrete floor construction combines concrete block with cast-in-place concrete slab and joists. The concrete block also serve as forms for the joists and the floor. A flat ceiling is produced that can be either plastered or painted. This type of floor system is efficient and simple to build and requires no special construction methods.

Solid reinforced concrete slabs 4 to 6 in. thick are also used in residence floor construction. The flat undersurface may be painted or plastered.



Three features of durable, firesafe construction are shown here: walls of concrete masonry, concrete floors —here shown supported on precast concrete joists—and a firesafe roof of asbestos-cement shingles or concrete tile.

Outdoor living areas are becoming increasingly popular throughout the nation. A concrete terrace and swimming pool, plus concrete flagstones, add much to the appearance and livability of this house; yet they are easy to keep clean and inexpensive to maintain.

In sections of the country where basements are less commonly used—the South, Southwest and certain areas of the Pacific Coast—slab-on-ground floor construction is becoming increasingly popular. A major reason is that it offers protection against termites, an important consideration in warm climates.

An increasing percentage of new houses have concrete subfloors for at least the first floor. Roofs of asbestos-cement shingles (see page 111) or concrete tile are also popular.

Footings, Foundations and Basements

Because of its great strength concrete is ideal for constructing footings, which prolong the life of the house by assuring uniform distribution of the weight of the house on the soil. Footings for foundation walls should be built on firm soil below possible frost penetration.

A basement constructed of concrete walls, concrete footings and a concrete floor can be a most useful and attractive part of the home. For houses without a basement a properly constructed concrete slab-on-ground floor helps to insure comfort and complete protection against rot and termites.

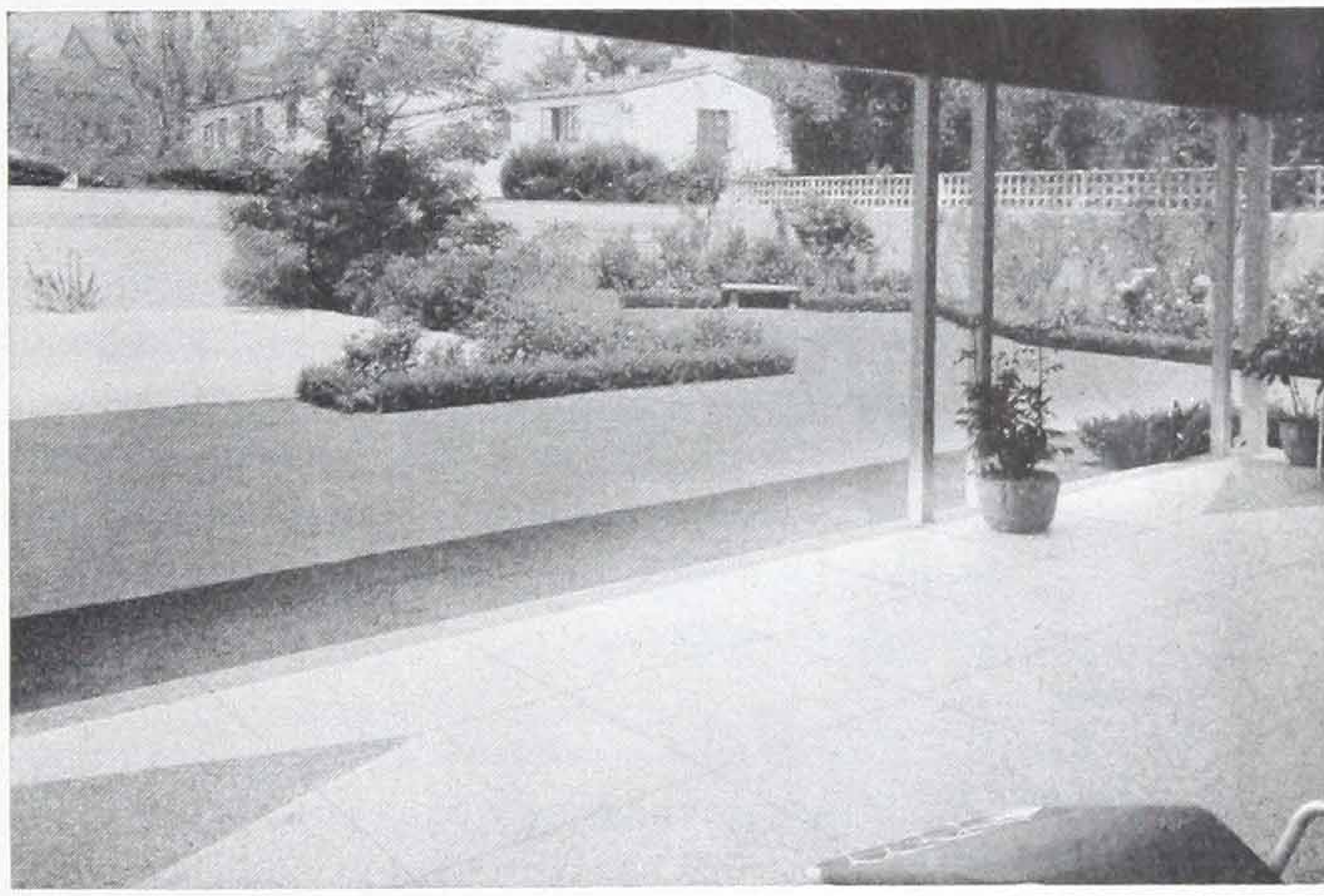
During the last few years, the increasing popularity of the one-story ranch house has influenced many home-owners in all sections of the country to build without a basement. The ranch house, however, was originally designed for warm, arid climates, and home-owners in colder climates are now recognizing the advantages of a basement, or at least a partial basement.

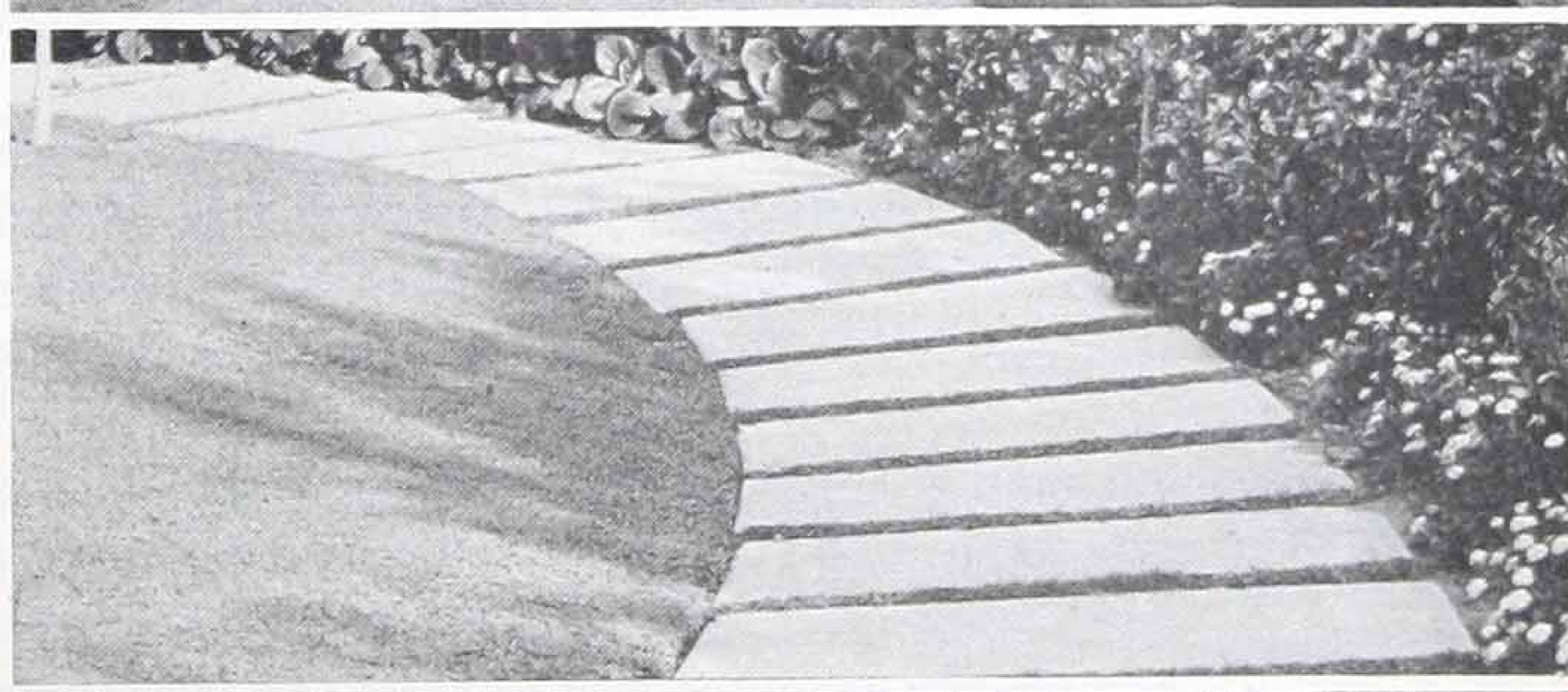
Probably the greatest single advantage a basement offers is ample, uncrowded storage areas. Space for heating and laundry equipment, for a recreation room or work shop, for storage of food, garden equipment and tools is provided economically. In the building of any new house, a certain amount of excavation is necessary, and with only a little additional excavation and depth of foundation walls, a basement can be provided. Since there is no need for storage and work areas to be built above the ground, a house with a basement occupies less of the lot and more space remains for lawn, garden, terraces and other adjuncts of modern living.

No discussion of concrete for housing is complete without mention of the many ways in which concrete can be used for the outdoor improvements that play such a great part in giving a property charm and personality.

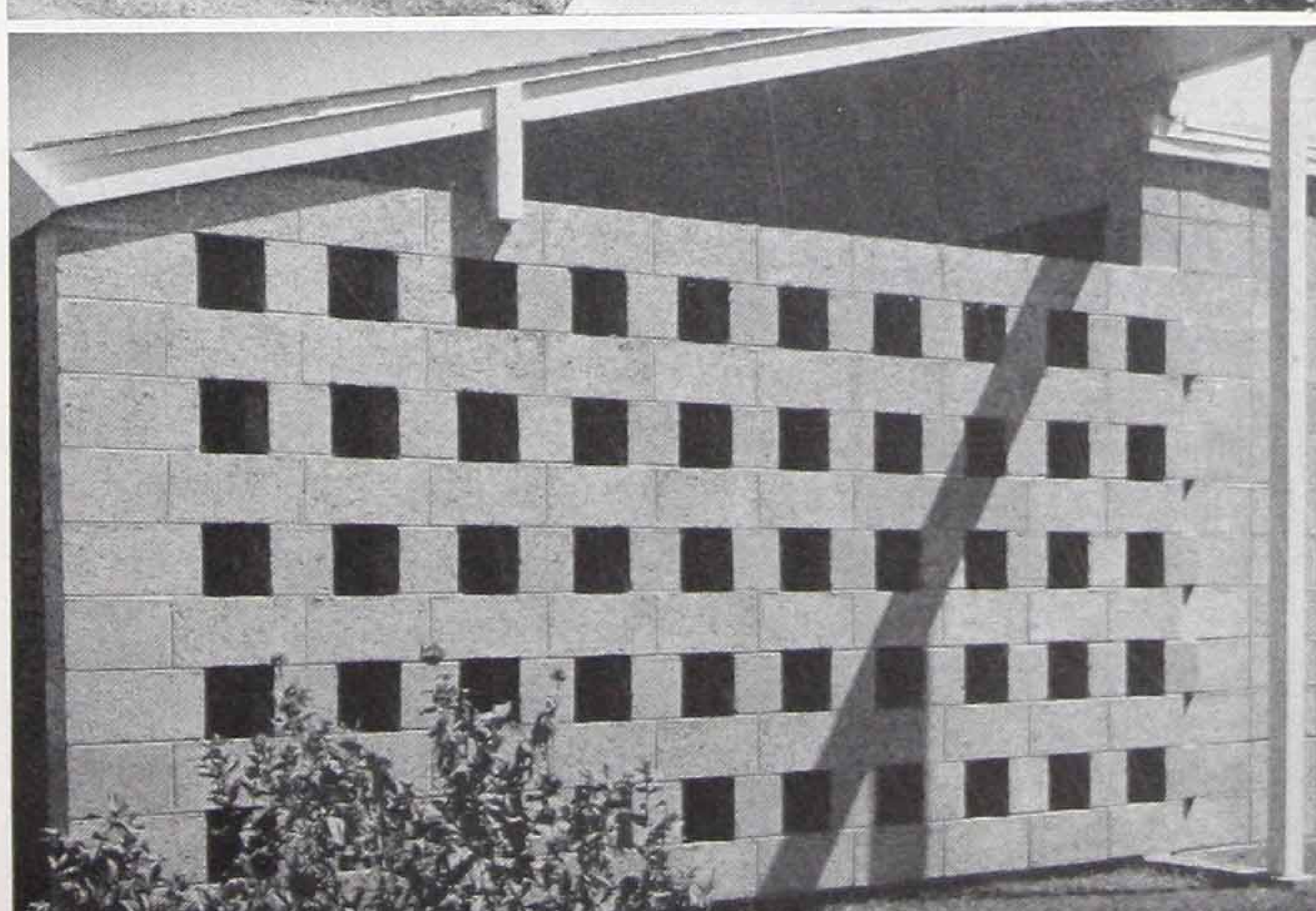
Outdoor Living

Some of the more popular concrete improvements around the home are sidewalks, driveways, play courts (for tennis, badminton and shuffleboard), fireplaces, lily ponds, garden walls and benches, bird baths, flagstone walks and swimming pools. These concrete improvements for better living can be built economically and will give long years of service.





The versatility of concrete is demonstrated by its many uses in and around the home, some of which are shown here.



ON THE farm, the uses of concrete are almost as varied as the duties of the farmer. Concrete makes his work easier and at the same time increases farm profits—by enabling him to save labor, conserve feed and food products, and increase production of farm crops, livestock, and dairy and poultry products. For the farm home and other buildings, for drainage and irrigation pipe and canals in the field, the farmer finds concrete the answer to his problem.

For Firesafety

In building his home, the center of all farm operations, and his livestock buildings for housing dairy and beef cattle, hogs and poultry, the farmer finds the firesafety of concrete an invaluable property.

According to National Fire Protection Association figures for 1953, about $139 million worth of property is destroyed each year as a result of farm fires. Farm families know only too well how important it is to eliminate combustible materials from farm construction.

For Farm Homes

For modern farm houses, with their up-to-date room arrangements, styling, utilities and other conveniences, concrete is the ideal building material. Exterior walls are often built with concrete masonry and then painted with portland cement paint. Concrete masonry interior walls are frequently left exposed and painted in a variety of colors. The basement, built with 8- or 12-in. concrete masonry units and a concrete floor, frequently serves as a large wash-up area for the modern farm home. All of these uses of concrete create an attractive farm home for the modern farmer and his family.

For Sanitation and Water Supply

Yet another application of concrete on the farm is for sanitation and an adequate, safe water supply. Concrete casings around wells and a concrete platform over the well assure a pure water supply, while a concrete septic-tank sewage-disposal system enables farm families to enjoy the conveniences of modern plumbing.

For Raising Pigs

"Pigs is pork" to the farmer only when he realizes a profitable return on his investment. According to the American Veterinary Medical Association, about 37 per cent of the hog crop is lost before hogs can be sold. Careful attention to the essentials of sanitation probably does more than any one thing to turn this potential loss into profit.

After small pigs have been successfully farrowed, the farmer is confronted with

Modern farm structures are highly functional and may differ markedly in appearance from the conventional concept of such buildings. This efficient Tennessee dairy barn has areas for bedding, automatic feeding and pipeline milking. Yards, gutters, walkways and floors are of easy-to-clean concrete, and all buildings are of concrete masonry.

the problem of increasing their weight to the 200-lb. market size in six months. Modern methods of raising pigs economically and profitably and of controlling disease make the use of concrete farrowing houses and concrete-paved feeding areas almost mandatory.

For Dairy Cattle

Modern dairy barns, adapted climatically to each section of the country, are efficiently arranged to reduce chore time and steps. They are built for ease in cleaning—permitting the production of high-quality milk with less effort. Concrete is widely used by dairymen to achieve this goal.

Labor- and time-saving features are incorporated in each of the three most generally used types of concrete dairy structures: stall barns, loose-housing barns, and milking barns.

Stall barns may be either one- or two-story buildings. For the one-story building, 8-in. concrete masonry units are used for wall construction. For two-story barns, since feeds are generally stored overhead, 12-in. units are used for the side walls. Exterior walls can be built with either heavy or lightweight units depending on the insulation requirements of the area.

When placed next to a stall barn, auxiliary buildings—the milkhouse for cooling and storing, the feed room and the silos—save the dairyman time and steps. They are usually linked to the feeding and milking areas of the barn by concrete walkways and alleys.

Old farm buildings are given new life at moderate cost through remodeling. Here concrete footings and foundations and concrete masonry walls add strength and durability and provide easier maintenance for an old barn.

In a loose-housing dairy arrangement, cows are sheltered and bedded in an open barn or shed. The side walls of these buildings are built with 8-in. units on an 8x16-in. concrete footing placed below the frost line. Cattle have free access to a concrete-paved yard and feeding area.

In mild climates, the milking barn is the principal dairy structure. It usually includes areas for milking, for handling and cooling milk, and for storing grain. Concrete walkways, paved corrals and feed mangers are important outdoor dairy improvements for sections with mild climates.

For Beef Cattle

One-story concrete masonry buildings—open on one side and coupled with a paved yard—make efficient housing for beef cattle production. These buildings, 30 to 40 feet wide and of any length desired, require little or no maintenance.

Concrete masonry units in the walls of such structures are usually left unpainted.

For Feeding Floors and Barnyard Pavements

Concrete feeding floors for hogs and barnyard pavements for cattle are farm improvements that return large dividends. Tests show that cattle confined in deep mud for 30 days lose weight even though they eat the same amount as when fed in a mud-free lot. Concrete-paved feeding floors create large savings in feed costs.

Mud is also a good carrier of disease organisms that take their toll from dairy cattle and hogs. Diseases can be curbed by following a sanitation program and paving feeding lots with concrete.

Concrete saves fertilizers as well as feed. Forty head of hogs on feed for 120 days produce the equivalent of 19 sacks of ammonium nitrate, while 250 sacks of the same fertilizer would be produced by 40 dairy cattle in a year. Much of this is lost on a dirt yard—with consequent loss of money by the farmer.

When pavement area is being estimated, hogs require 15 sq.ft. of pavement per head; dairy cattle, 75-100 sq.ft. per head; and beef cattle, 30-40 sq.ft. per head.

Concrete-paved yards are generally 4 in. thick for all types of livestock. If heavily loaded grain trucks or other equipment are driven frequently along the edge of the yard those sections of pavement should be 6 in. thick.

For the nonslip surface required in a barnyard, a long-handled steel brush or stiff fiber brush is stroked across the surface of the fresh concrete.

For Poultry

The production of eggs and poultry meat is a profitable specialized business—in many cases approaching production-line techniques and efficiency.

One of the poultry farmer's most pressing problems is maintaining high egg production during the winter months when egg prices are the highest. To accomplish this, the flock must be kept vigorous, healthy and active throughout the winter. Concrete masonry has found great favor in construction of warm, dry, well-lighted and properly ventilated poultry houses.

Multiple-story poultry houses make possible maximum labor efficiency in modern poultry and egg plants. These efficient poultry "factories," when of concrete masonry construction, require little or no maintenance, and concrete interiors provide smooth surfaces that are easily cleaned and have no crevices to harbor

poultry parasites. Concrete construction also effectively keeps out rats, weasels and other rodents.

For Silos

Silage for winter use—cut, compressed, and preserved by its own fermentation in an airtight chamber—increases dairy and stock farm profits. The farmer who feeds silage to his dairy herd, beef cattle or sheep gets the full value out of his forage crops—the 40 per cent in the stalks and leaves as well as the 60 per cent in the ears and grains.

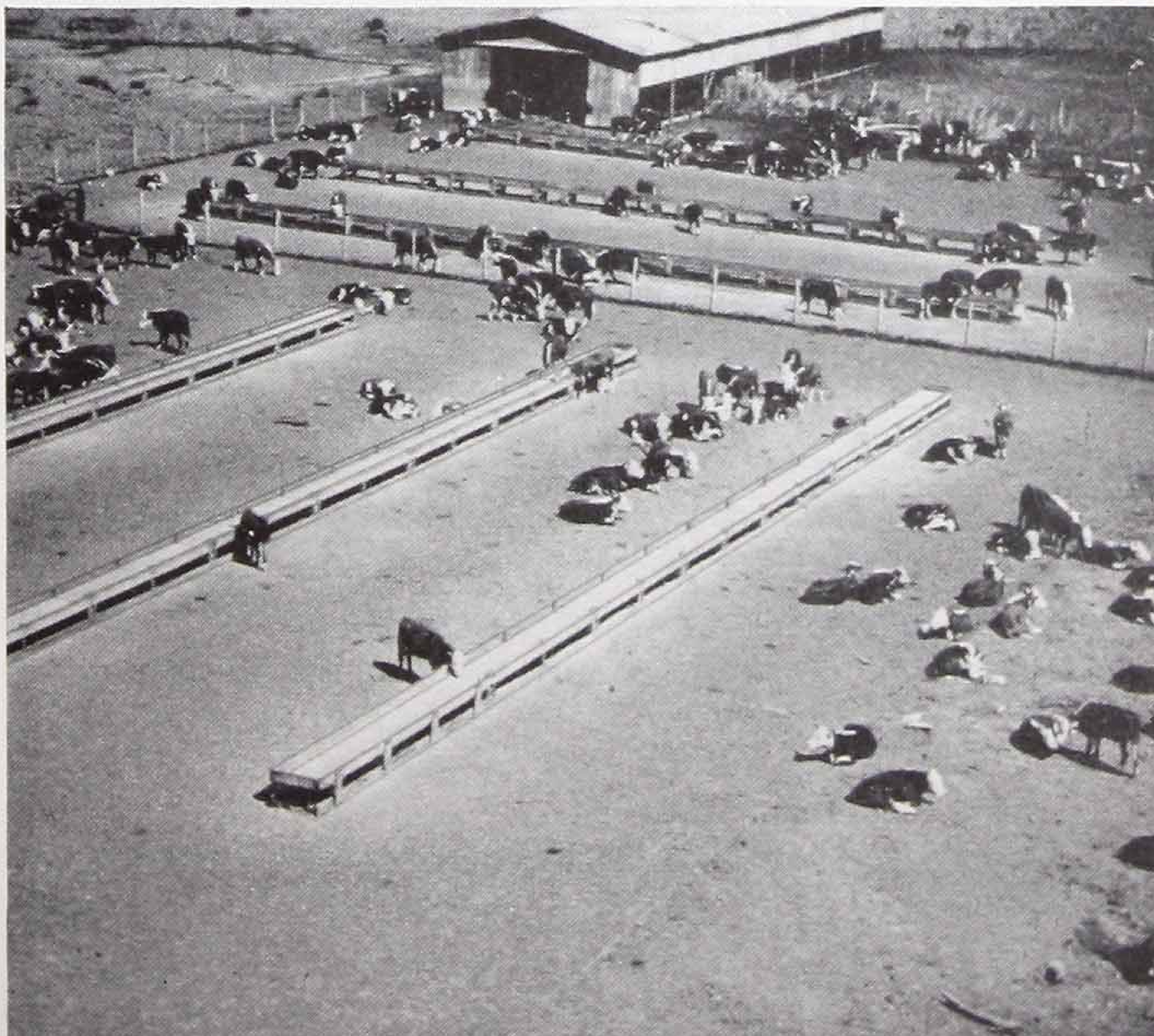
Concrete stave silos are constructed of hundreds of interfitting units about 10 in. wide, 30 in. long and 2½ in. thick. As the staves are being fitted to form the walls of the silo, steel reinforcing rods are tightened to hold firmly against internal pressure—like hoops on a barrel. Cast-in-place silos are constructed by placing concrete in circular forms, which are raised as construction progresses. The concrete walls are usually 6 in. thick and are reinforced.

For Remodeling

Many outdated farm structures, such as general-purpose or horse barns, are restored to new usefulness as Grade A dairy barns, poultry houses, beef cattle barns or utility buildings at a fraction of the cost of constructing new buildings. In the repair or reconstruction of such old structures, one or more of the following processes is nearly always involved:

Replacing stone or pier foundations with cast-in-place concrete or concrete block.
Replacing rotted and sagging walls with new concrete block walls.
Replacing dirt floors with concrete pavement.
Re-siding and re-roofing with asbestos-cement products.

Concrete, concrete masonry and asbestos-cement products are ideal construction materials for remodeling. They are economical in first cost and have the long-term advantages of durability and low maintenance cost.



The largest concrete-paved barnyard in the world, near Havana, Ill., pays for itself in savings of fertilizer and feed, and faster weight-gain of the livestock.

Precious water is saved and farm labor reduced with concrete-lined irrigation ditches such as this one in the Rio Grande Valley of Texas.

For Preventing Soil Erosion Many farmers, fighting to check waste from soil erosion, use concrete structures to control the velocity and flow of runoff water. Two types of construction are commonly used. One type is the concrete check dam, which retards runoff that causes land-destroying erosion. The other type is the flume—a concrete-lined sloping channel—which diverts water runoff and prevents washing out of soil.

For Drainage and Irrigation Concrete drain pipe 5 in. in diameter is the minimum size recommended for farm drainage. These are laid in lines 3 to 4 ft. deep, and from 30 to 300 ft. apart, depending on the kind of soil. Strength and absorption are the measures of drain-tile quality. Standard concrete drain tile tests at least 1,200 lb. per lin.ft. in strength and not over 10 per cent in absorption. Extra-quality tile must test at least 1,600 lb. per lin.ft. and not over 8 per cent in absorption.

Concrete pipe 10 in. and larger in diameter is used for the conveyance of water to many thousands of acres of land. In some cases these lines are buried 4 to 5 ft. below the surface. Hills present no problem because the pipe irrigation systems operate under pressure. A concrete pipe system properly installed requires very little maintenance.

In some sections of the country, the terrain lends itself to the use of open ditches for the conveyance of water to the crops. Concrete-lined canals reduce absorption losses and save water for crop use. These canals are generally 12 to 14 in. wide at the bottom and 2 to 3 ft. at the top, depending on the quantity of water to be delivered and the slope of the ditch. Concrete linings are $2\frac{1}{2}$ to 3 in. thick. They may be made with forms pulled steadily down the ditch by a tractor, or with sectional forms that are manually moved.

SOUND, sensible programs and policies for the conservation and development of America's natural resources are gaining increased attention. In the past, the country's abundant water resources have been neither wisely used nor adequately developed. Extensive clearing and draining of lands have made rainfall runoff more rapid, with a consequent increased intensity of floods, erosion of tillable lands and shrinkage of underground storage reservoirs. In many localities the gradual lowering of the groundwater level is affecting the domestic and industrial water supply, and many cities are going great distances to tap some large surface supply of water. Other cities are expanding present sources of supply. Tulsa, Okla., is an excellent example. In 1924, Tulsa built what was then a record-breaking concrete pipeline to bring water to Tulsa's citizens and industry. A parallel concrete pipeline—nearly 160,000 ft. of 66- and 72-in. high-pressure pipe —was completed in 1951 to double the previous supply and insure Tulsa 67 million gal. of water daily.

While too little water creates serious economic problems, too much water takes a vast toll of natural as well as man-made resources. It has been estimated by the U.S. Department of Commerce Weather Bureau that floods caused property damage of nearly $2½ billion in the United States during the five-year period 1951–1955. Damage from floods in 1955 alone totaled more than $900 million. Nearly every part of this country has its flood history and in many sections permanent flood-control structures have become an important part of the landscape. At Portsmouth, Ohio—to cite one instance—three miles of concrete walls built to keep out a stage of 77 ft. in the Ohio River have repeatedly protected that city from floods that caused millions of dollars damage to less adequately protected towns and cities in the Ohio Valley.

Agencies Work on Flood Control

Many agencies are constantly working on remedial measures to avoid repeated cycles of floods, devastation and rehabilitation. The work of the Department of the Army, Corps of Engineers, in the construction of flood-control structures and the dredging of rivers and harbors; of the Bureau of Reclamation in the construction of huge dams for irrigation, power and conservation; of the Department of Agriculture and the Soil Conservation Service in the conservation of land is well known, but frequently not fully appreciated.

Today's flood-control work is the result of years of increasing understanding of the relationships between watersheds, soil erosion and floods—gained from

Section 5 — CONCRETE IN CONSERVATION

experience, research and continuing study. In this connection it is interesting to note the work of the Concrete Research Division and Waterways Experiment Station, Department of the Army, Corps of Engineers, at Vicksburg, Miss. Here numerous models of 1-to-16, 1-to-20 and similar scale replicas of areas, rivers and structures under study furnish practical information to government agencies and the engineering profession.

The most spectacular flood-control study ever undertaken and the largest hydraulic model in the world is the Mississippi River Basin model near Vicksburg, estimated to cost more than $6 million. This huge earth and concrete model is designed to further the study of flood control in the entire drainage basin of the Mississippi River and its tributaries. The model requires an area of about 200 acres to reproduce the 1,250,000 square miles of this drainage basin.

The Bureau of Reclamation maintains at Denver an extensive laboratory for use in its conservation and irrigation work.

Recently Congress authorized the U.S. Department of Agriculture to cooperate with local agencies in the development of flood control in the upper river basins. The purpose of such developments is to halt the falling water table by re-establishing underground water reservoirs; to prevent waste of water so that it can be utilized for supplementary irrigation, industrial and recreation use; and to prevent damage by water—that is, soil erosion, silting and floods.

This will supplement but not supplant direct flood-control measures such as reservoirs, levees and flood walls that are being constructed on principal waterways of the nation.

Shasta Dam in California is one of many that are being used to conserve our precious water supply, prevent flood destruction and provide water needed to make arid or drought-stricken land useful again.

Need for Irrigation

The population of the United States is increasing out of proportion to its acreage of cultivated lands. In 1915 the harvested crop lands totaled approximately 340 million acres; in 1950, 345 million acres. The population in 1915 was 100 million; in 1950, 150,697,000. Food production per acre has been increased by scientific farming methods to feed these 50 million more people on only 5 million additional acres of harvested crops. But it is doubtful that it will be possible to feed an additional 50 million, the anticipated increase in population by 1975, without a substantial increase in the acreage of cultivated lands.

It is estimated that there are approximately 80 million acres of arable land in the United States not now being cultivated, of which about 22 million can be irrigated. The limiting factor is water, not land. Therefore, it is important to conserve every drop of water that can be used for irrigation.

The construction of such huge dams as Hoover and Grand Coulee is an important part of the plan to transform desert land into productive acreage through harnessing water for irrigation and power. Hoover Dam on the Colorado River near Boulder City, Nev., is 726 ft. high (approximately the height of a 50-story building) and contains almost 7 million tons of concrete. It has a total power capacity of 1,725,000 hp and provides storage capacity for a series of dams downstream from which water is drawn for irrigation and domestic use in southern California and Arizona.

Grand Coulee Dam, on the Columbia River in northern Washington, is 550 ft. high and 4,300 ft. long at the top, and contains almost 24 million tons of concrete. It is the world's most massive dam, containing the world's largest hydroelectric plant, rating 2,700,000 hp of electric energy; and the world's largest pumping plant, consisting of 12 pumps, each with a capacity of 720,000 gal. per minute. Water is lifted 280 ft. from a reservoir behind the Grand Coulee Dam to a 27-mile long equalizing reservoir in an ancient channel of the Columbia River that was blocked during the glacial period. From here water flows through concrete-lined canals, concrete siphons and concrete pipelines to the farm lands. More than 350,000 acres have already been supplied with water and ultimately this project will furnish irrigation water for more than a million acres.

Water Needs on the Rise

An adequate water supply is a vital requirement for urban and industrial development. However, many of our public water supplies are presently inadequate to provide sufficient water for maximum requirements in accordance with good water-works engineering practice. Thus, a large number of cities and communities are spending vast sums to increase their water supply and provide for future needs.

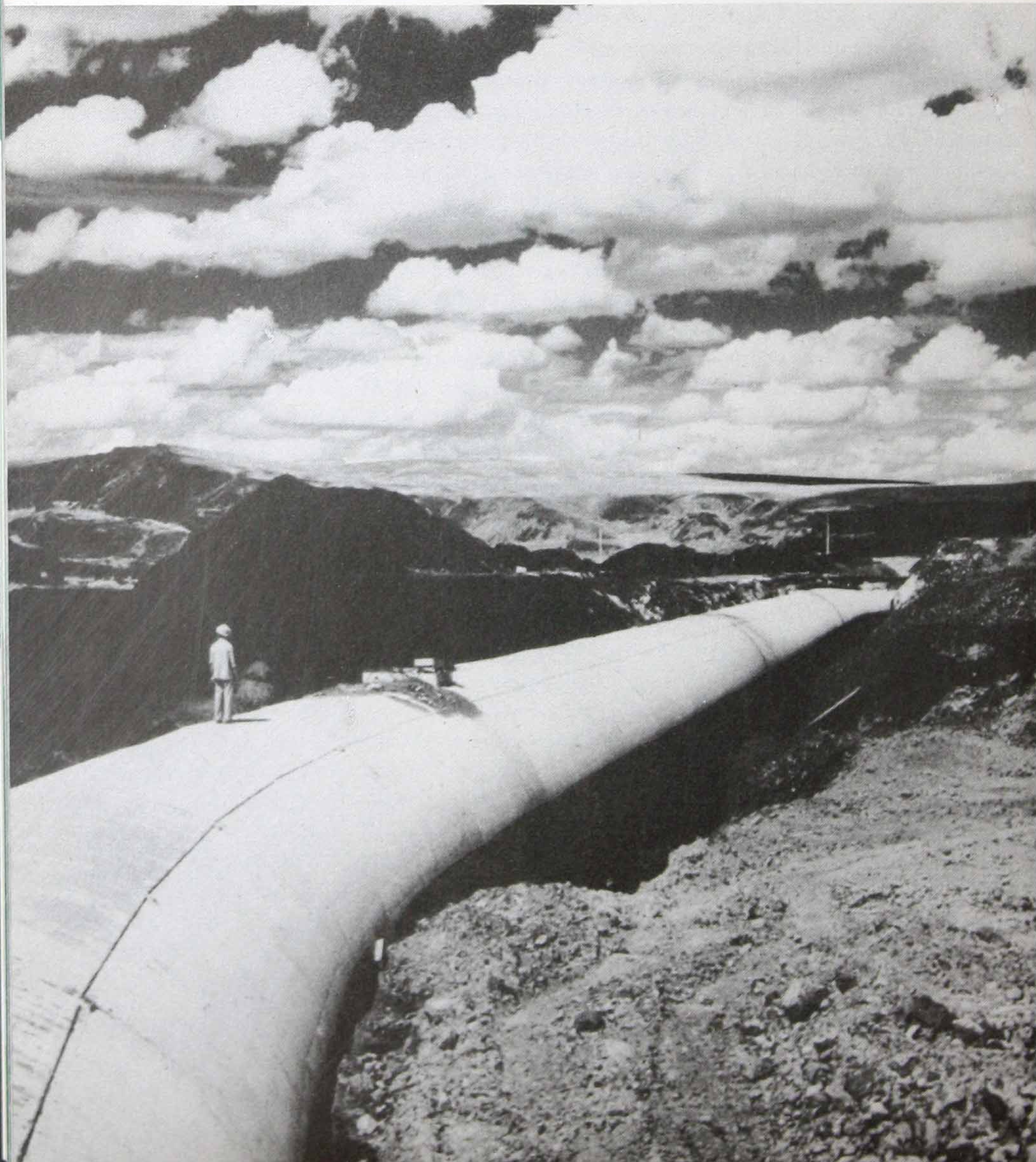
For example, New York has expended some $440 million to complete the first two stages of its Delaware River water supply. It will furnish 540 million gal. per day to New York City. This work included the construction of three dams, three reservoirs, and 115 miles of concrete-lined tunnels from 10 to 19½ ft. in diameter. The third stage, now authorized at an estimated cost of about $400 million, will increase the water supply to a total of 800 million gal. per day.

In 1954 Boston completed a 7-mile long, 10-ft. diameter concrete water tunnel

from the city's Chestnut Hill Reservoir to the suburb of Medford at an expenditure of $11.9 million.

In 1954 a high-pressure concrete pipeline totaling about 50 miles was constructed from the Colorado River Aqueduct to the San Vincente Reservoir to increase San Diego's water supply by 95 cu.ft. per second. This line parallels a similar line that was constructed in 1947.

This concrete siphon, 25 ft. in diameter with walls 2 ft. thick, is capable of carrying 2½ million gal. of water per minute for irrigation of arid land in the Columbia Basin Project in the state of Washington.
—Photograph courtesy of the Bureau of Reclamation.



This attractive concrete seawall protects property along the Bayshore Drive in Tampa, Fla., from the destructive forces of wind and water.

Sanitary Demands Increase

A growing population, a better standard of living and greater industrial activity have caused production of larger quantities of waste materials. A large proportion of these wastes is discharged untreated or only partially treated back into the streams and lakes of the country. Such pollution renders streams unsuitable as sources of water supply, hinders navigation, decreases property values and ruins recreational areas.

As the needs and problems have arisen, local and federal organizations have established teams of experts to deal with the emergencies. Recently the Water and Sewage Industry and Utilities Division of the Business and Defense Services Administration made a detailed study and estimate of the sanitation needs for the next 10 years. These estimates were based on present deficiencies, needs to offset obsolescence and depreciation, and future growth. The estimated construction needs totaled \$25,330 million, of which some \$10,730 million was for water works, and \$14,600 million for sewage works.

concrete masonry

THE term "concrete masonry" is applied to block and brick building units molded of concrete and laid by masons in a wall. Minimum requirements for these units are set forth in local building codes and Federal Specifications, and by the American Society for Testing Materials or other agencies that develop specifications.

Every state in the Union and every province in Canada is represented in the total of more than 4,500 active concrete masonry plants, many of which turn out more than 10 million masonry units in a year. Each of these larger producers manufactures enough concrete masonry units a day to build a dozen moderate-sized homes.

Concrete masonry units are made by mixing portland cement with water and suitable fine and coarse aggregates. Aggregates for heavyweight masonry units include sand, pebbles, crushed stone and crushed slag; for lightweight units, processed clays and shales, natural volcanic aggregates, cinders or processed blast-furnace slag are employed.

Concrete masonry units made with lightweight aggregates have been growing steadily in popularity in recent years. One important reason for this growth is that they are more easily handled on the job. Approximately 50 per cent of all concrete masonry units made today in the United States are produced with lightweight aggregates. It is estimated that about 19½ million cu.yd. of lightweight aggregates was used in 1954's block production.

Concrete masonry units are made in several sizes and shapes, all designed to permit speedy, economical construction. An 8x8x16-in. unit weighs about 45 lb. when made with heavyweight aggregates, and about 20 to 30 lb. when made with lightweight aggregates.

Standard Dimensions In 1938, the American Institute of Architects and the Producers' Council, Inc., through the American Standards Association, initiated an industry-wide movement to establish standard basic dimensions for the manufacture of building materials. This is known as "modular coordination." By coordinating the dimensions of building materials, costly cutting and fitting at the construction site would be minimized and construction costs substantially reduced. Concrete masonry units lend themselves readily to this relatively new system of modular coordination, and concrete masonry producers are rapidly converting to the manufacture of modular-sized units.

Concrete masonry lends itself to homes of any architectural design and is widely used in every section of the country.

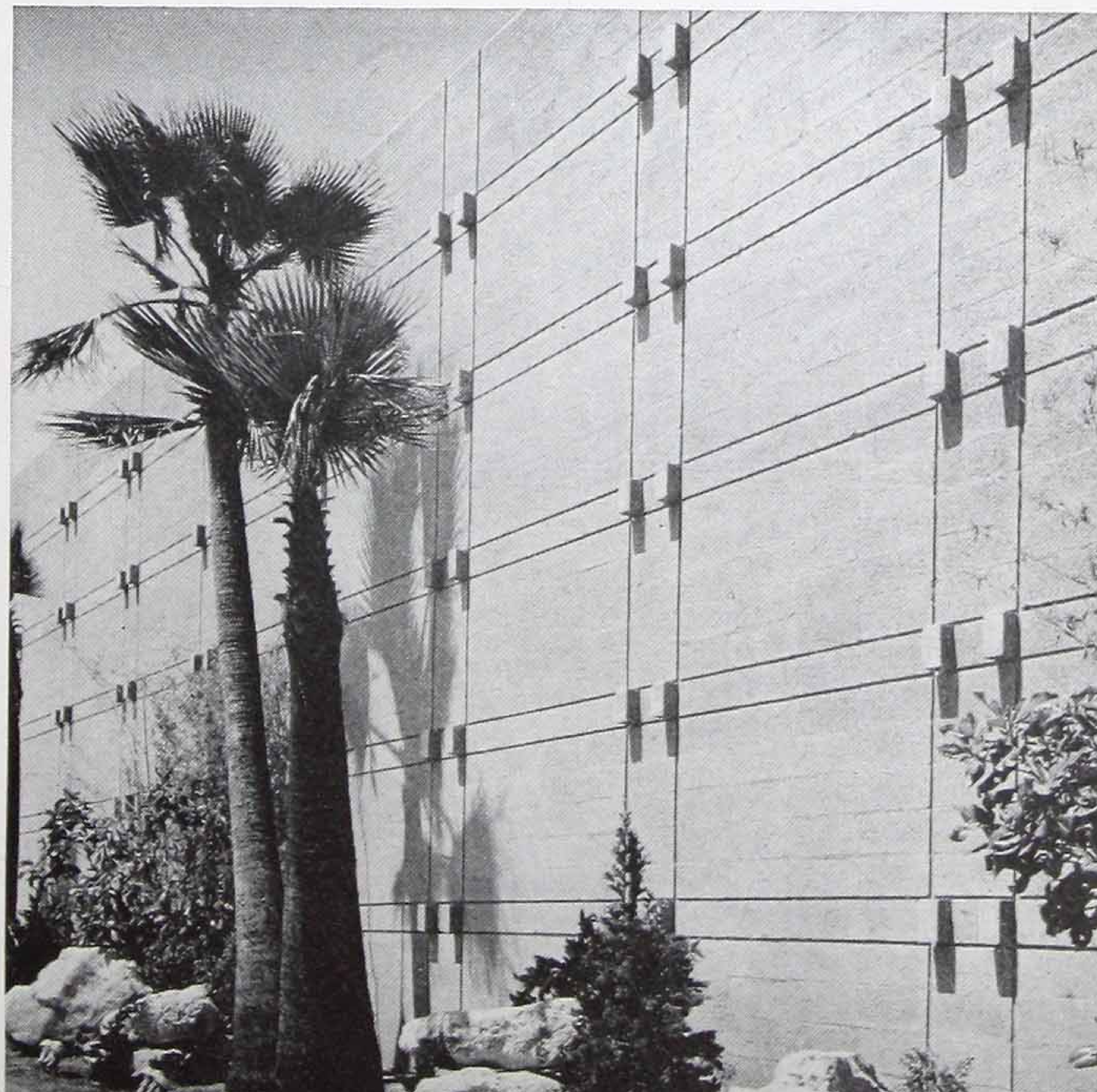
Manufacture and Uses

There are three principal steps in making concrete masonry units: the careful proportioning and mixing of portland cement, water and aggregates; molding of the units; and curing and drying.

Concrete units are used for all types of masonry construction including load-bearing and non-load-bearing walls; piers; partitions; fire and party walls; backup walls for brick, stone and stucco facing materials; fireproofing around steel columns, stairwells and enclosures; and chimneys. Many plants also make concrete masonry sills, lintels and floor filler units.

Total production of concrete masonry units was more than two billion in 1955. In terms of wall volume, concrete masonry represents more than two-thirds of all masonry walls built today. The advantages of concrete masonry that have led to this remarkable growth have been effectively demonstrated both by laboratory tests and by actual field performance.

Concrete masonry is being used to construct more than two-thirds of the volume of all masonry walls built today. Block was laid in an unusual decorative pattern for walls of this Nevada hotel.



Firesafety with Concrete Masonry

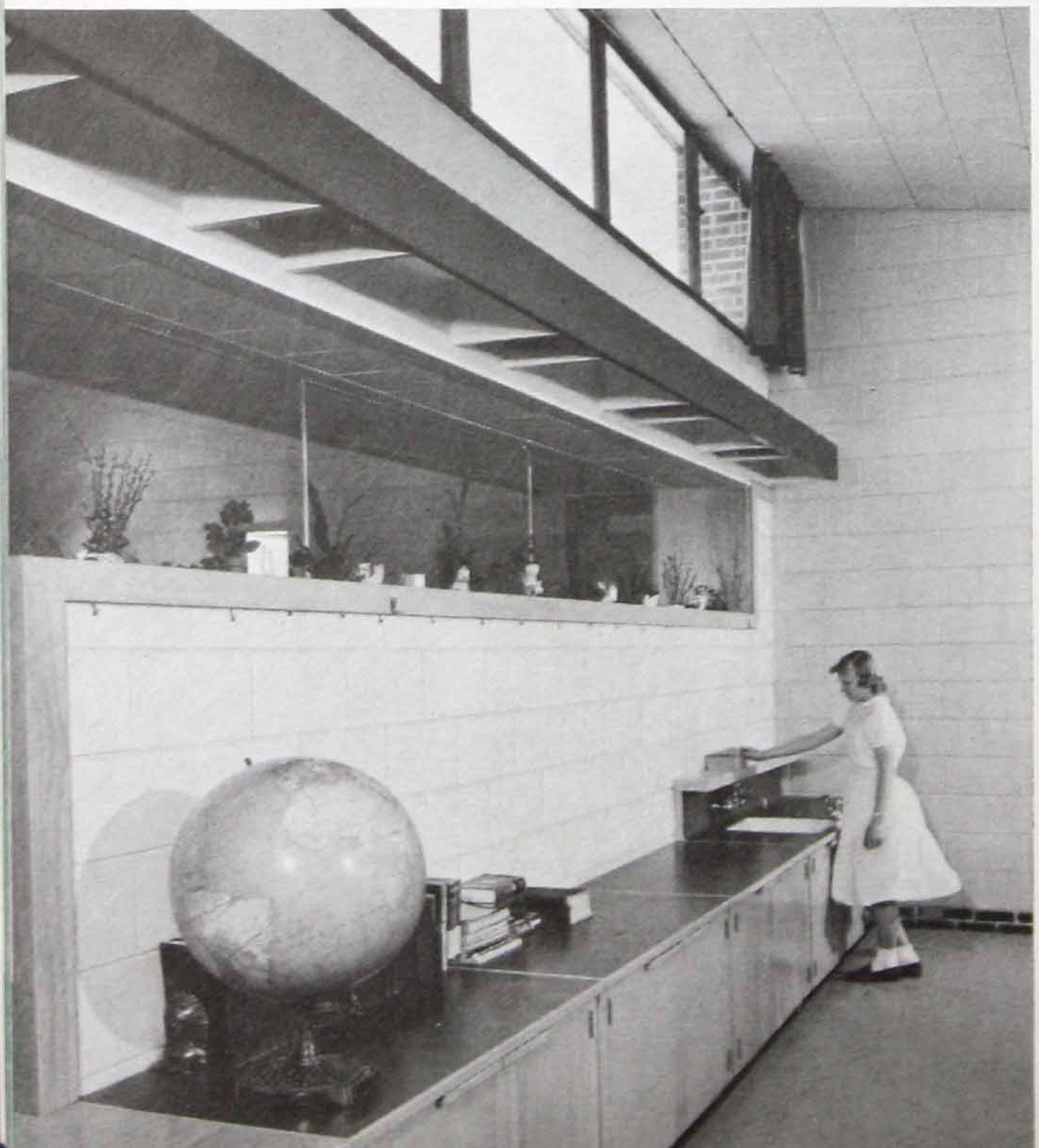
All structures, whether hospital, hotel, or bungalow, have one common formidable enemy—fire. The firesafe qualities of concrete masonry make it invaluable protection for not only property but—of much greater importance—human life.

Concrete masonry walls have substantial load-carrying ability and firesafety before, during and after severe fire exposure. Fire tests made on concrete masonry walls by Underwriters' Laboratories, Inc., demonstrated that concrete masonry units can be made to meet 2-hour, 3-hour and 4-hour fire-retardant ratings; these ratings are dependent on such factors as type of aggregates and thickness of the units. The scientifically based ratings of standard building materials by Underwriters' Laboratories are recognized nationally by architects and builders.

Sound Control Tests Made

Control of sound is now regarded as a necessity in practically all types of buildings. To determine the sound-absorbing qualities of concrete masonry, the Portland Cement Association in cooperation with the University of Illinois investigated concrete of different compositions and physical properties.

The test results show that concrete walls, even with dense surface textures, are more sound-absorbent than the usual hard plaster. Open-textured concrete masonry has a very high acoustical rating. Any material absorbing sound to the extent of 15 per cent or more is regarded as a useful acoustical aid. Concrete masonry can be made to absorb as much as two-thirds of the sound. Concrete masonry also resists the transmission of sound, so that outside noises do not interfere with activity in a room.



Open-textured concrete masonry units were used for the interior walls of the Washington Irving School, in Waverly, Iowa. The sound-absorbent quality of such walls makes them especially useful for interior walls of theaters, auditoriums, classrooms, and wherever good acoustics are important.

concrete pipe

MANY thousands of miles of concrete pipelines—ranging in size from 4 in. to 32 ft. or more in diameter—serve the people of the United States in innumerable ways. In the transportation of water to cities and arid farm lands; in the removal of used water and surplus rainfall; in the building of drainage structures on railroads and highways; in the reclaiming of lands and in the housing of underground telephone, telegraph and electric cables; and in many other ways, concrete pipelines are doing a vast job of public service.

More than 80 million people in this country obtain water from public supplies—a total of 8 billion gal. daily. Concrete pressure pipelines help transport this water from reservoirs, lakes, rivers and wells. Sometimes these pipelines run over mountains and under rivers into our cities. To name but a few, Tulsa, San Diego, Denver, Detroit, Salt Lake City, East St. Louis and Victoria, B.C., have recently put concrete pressure pipe to work in water supply lines. Specially designed reinforced concrete pressure pipe have been built to withstand water pressures of more than 500-ft. head. On a 5-ft. diameter pipe, this would be equivalent to an internal pressure of 244 tons per lin.ft. of pipe.

Sanitation and Sewage Disposal

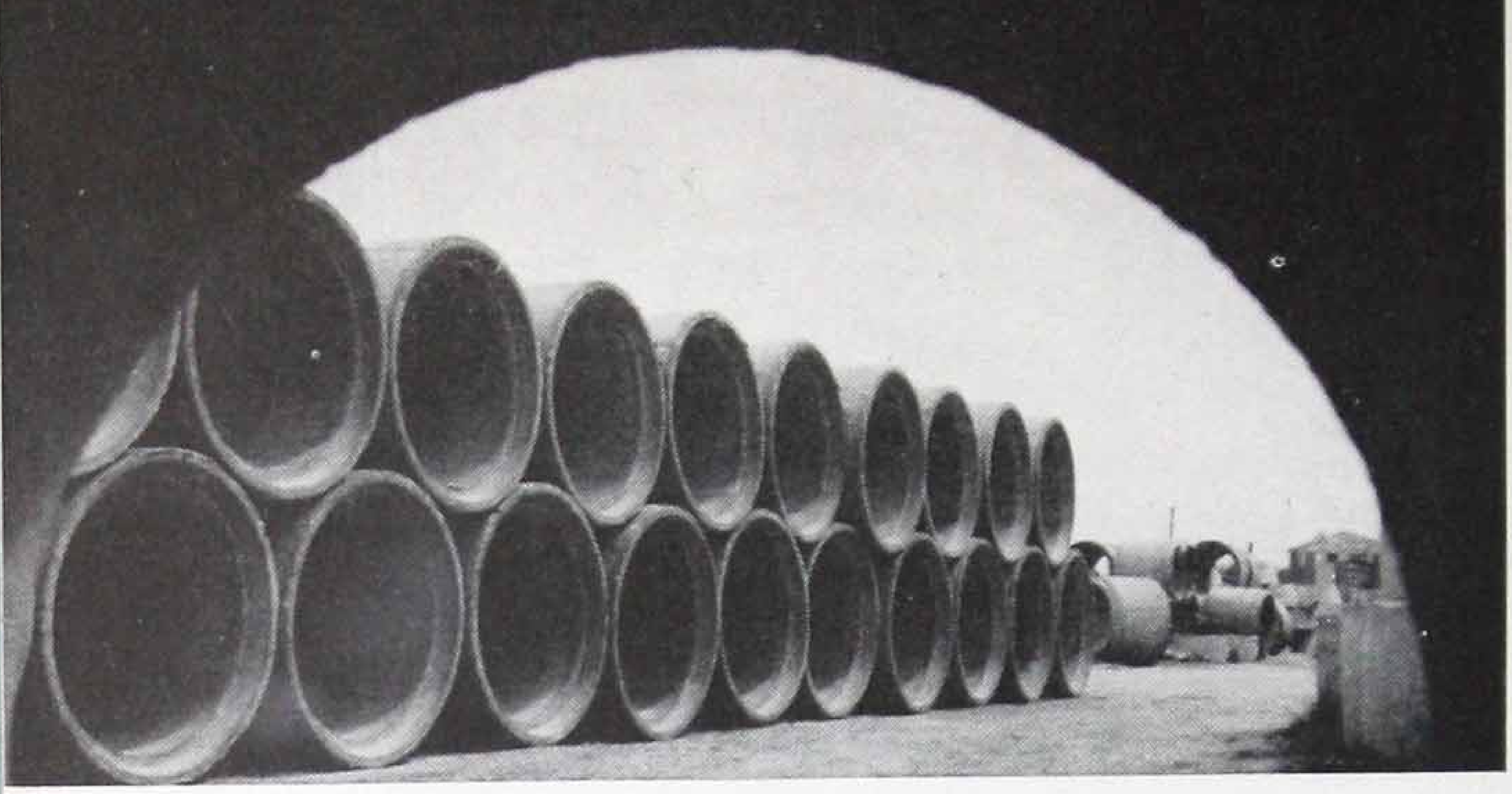
The first known concrete pipe sewer in the United States was constructed in 1842 at Mohawk, N.Y. Since that time, the use of concrete pipe has grown steadily. In 1920, standard specifications for concrete sewer pipe were adopted by the American Society for Testing Materials. This, together with improvements in manufacturing equipment, insures high quality.

Today concrete pipe are used either exclusively or in part in many cities throughout the United States and Canada for storm, sanitary and combined sewer systems. Some of this sewer pipe is large enough for a truck to be driven through. Sewerage systems are often many miles in length. For example, Los Angeles has more than 1,500 miles of concrete pipe—ranging in diameter from 8 in. to 12 ft. Houston, Texas, has more than 700 miles.

Concrete Irrigation Pipe

The use of concrete pipe for irrigation in this country began in 1888 in California. Today there are almost twice as many miles of concrete irrigation pipelines in that state as there are miles of primary and secondary roads—and the use of concrete pipe is spreading rapidly to other states.

Each year between 20 and 60 per cent of the irrigation water transmitted in unlined channels is lost before it reaches the farm lands. A large portion of this loss is due to seepage and evaporation. Concrete irrigation pipelines, because of their watertightness, prevent seepage and the loss of land through waterlogging.



Rugged durability and long life are qualities that have made concrete sewer pipe widely used.

Because concrete pipelines are enclosed conduits, evaporation losses are negligible. And because they are usually placed underground, their use does not require the setting aside of productive lands for the construction and operation of open ditches.

Solving Drainage Problems

Concrete pipe are used in many ways for underground and surface drainage. As one example, the productivity of many acres of farm land in this country is dependent on proper underground drainage. In this vital work concrete drain tile play an important part.

In the larger sizes, concrete pipe are used to solve many different types of drainage problems—among them the disposal of surface storm-water runoff on rural highways and city streets and the drainage of manufacturing sites, ball fields and parks. Uninterrupted airport service is oftentimes directly dependent on the quick and efficient drainage of the airfield. Concrete drainage pipe are doing this job in a majority of the principal airports in the United States. About 40 miles of concrete pipe was used to insure adequate drainage of New York International Airport (Idlewild).

For more than 40 years reinforced concrete pipe have been specified for building culverts and other drainage structures by the engineers of the principal railroads of the United States and Canada. Engineers also make wide use of reinforced concrete pipe in drainage structures for all types of highways.

Reinforced concrete pipe are giving excellent service today under fills ranging from 2 to 150 ft. These concrete pipe culverts, with a life expectancy of many decades, minimize maintenance costs.

Concrete culvert pipe serve equally well under deep or shallow fills because—properly designed, constructed and installed—they have ample strength to withstand heavy loads and to absorb severe impact. In large sizes and multiple lines, pipe are being increasingly used to replace wornout small bridges and low trestles. They can be quickly and easily installed and have the structural strength to permit their being jacked into place. Jacking is the process of forcing pipe through embankments or fills where open cuts are not desirable. The first section to be jacked into place usually has a cutting edge. The excavated material is then removed through the pipe. Other lengths of concrete culvert pipe are added as the excavation progresses.

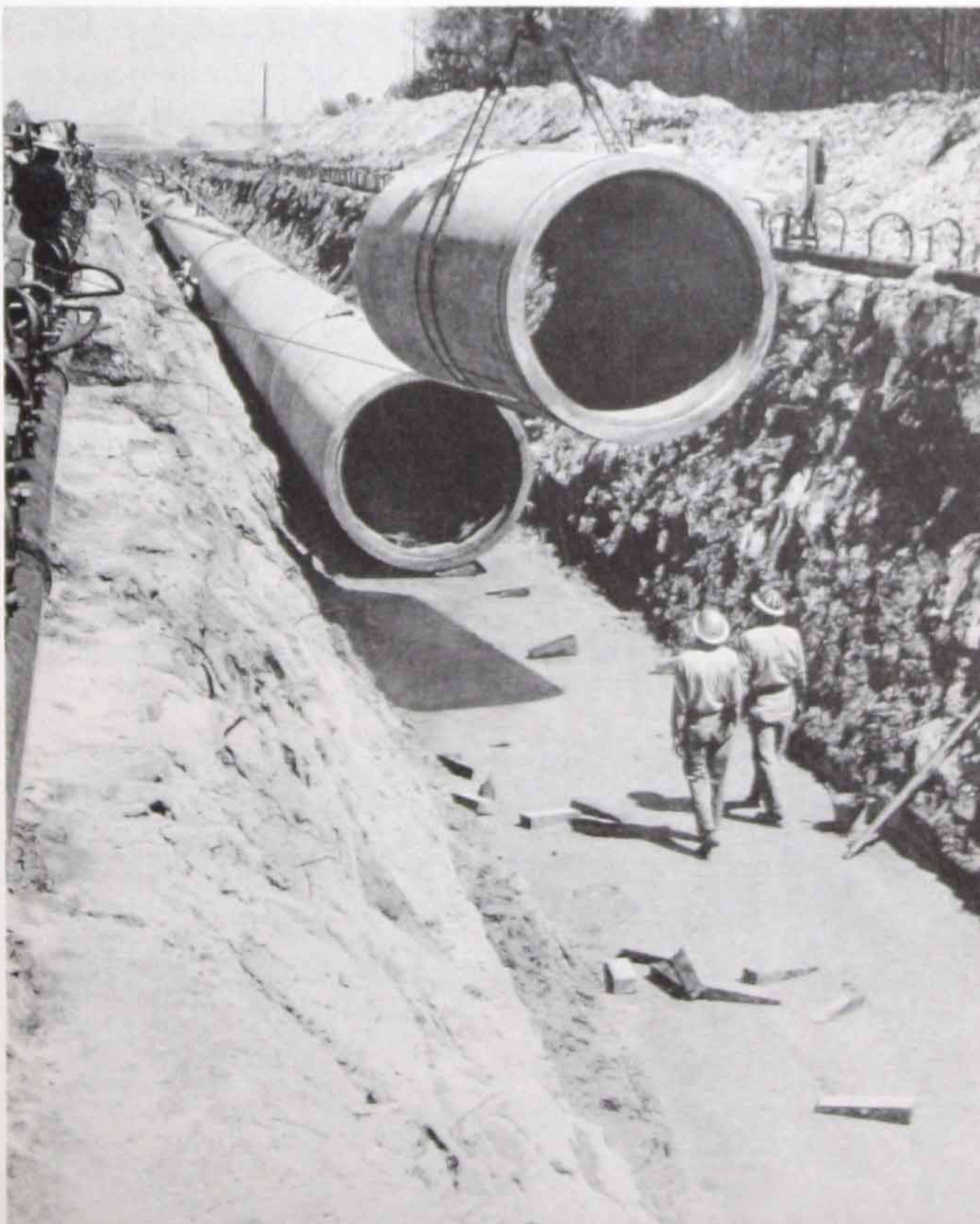
Some Dramatic Uses

More than 350 plants manufactured more than 13 million tons of concrete pipe in 1955, an increase of more than 7 million tons since 1947, according to figures estimated by the American Concrete Pipe Association. Concrete pipe can be designed for practically any combination of engineering requirements and local or climatic conditions.

Two examples will illustrate the almost unlimited possibilities of concrete pipe. The Alameda Estuary Tunnel between Oakland and Alameda, Calif., is believed to contain the largest concrete pipe in existence. Each section of pipe is 32 ft. in diameter and 203 ft. long. Sections were floated into the estuary, sunk to the bottom, and then assembled by divers. The concrete pipe section of this tunnel measures almost a half mile in total length, and would be large enough to permit some single-engine training planes to fly through it unscathed.

In another instance, a pedestrian underpass of 8-ft. reinforced concrete pipe was constructed under the four main tracks of the Delaware, Lackawanna and Western Railway in Elmira, N.Y., to provide a safe crossing for children. The pipe was jacked under the tracks without interruption of traffic. A 5-ft. wide concrete walk was constructed in the bottom of the pipeline, which has an overhead clearance of more than 7 ft.

Many other examples could be cited of the use of concrete pipe for underground installations of water and gas mains and telephone, telegraph and electric wires and cables.



Production of materials for nuclear weapons requires enormous quantities of water. Forty-eight miles of concrete pipe carry water from the Savannah River to the South Carolina atomic energy project.

precast structural members

THE scope of the various uses of precast concrete structural members is broadening rapidly and today covers nearly every field of construction. A partial list would include piles and decks for railway and highway bridges, floor and roof slabs, wall panels, joists, beams, girders and rigid frames.

Precast concrete structural members can be made at a central precasting plant and then shipped to the building site where they are put in place, or they can be cast at the building site.

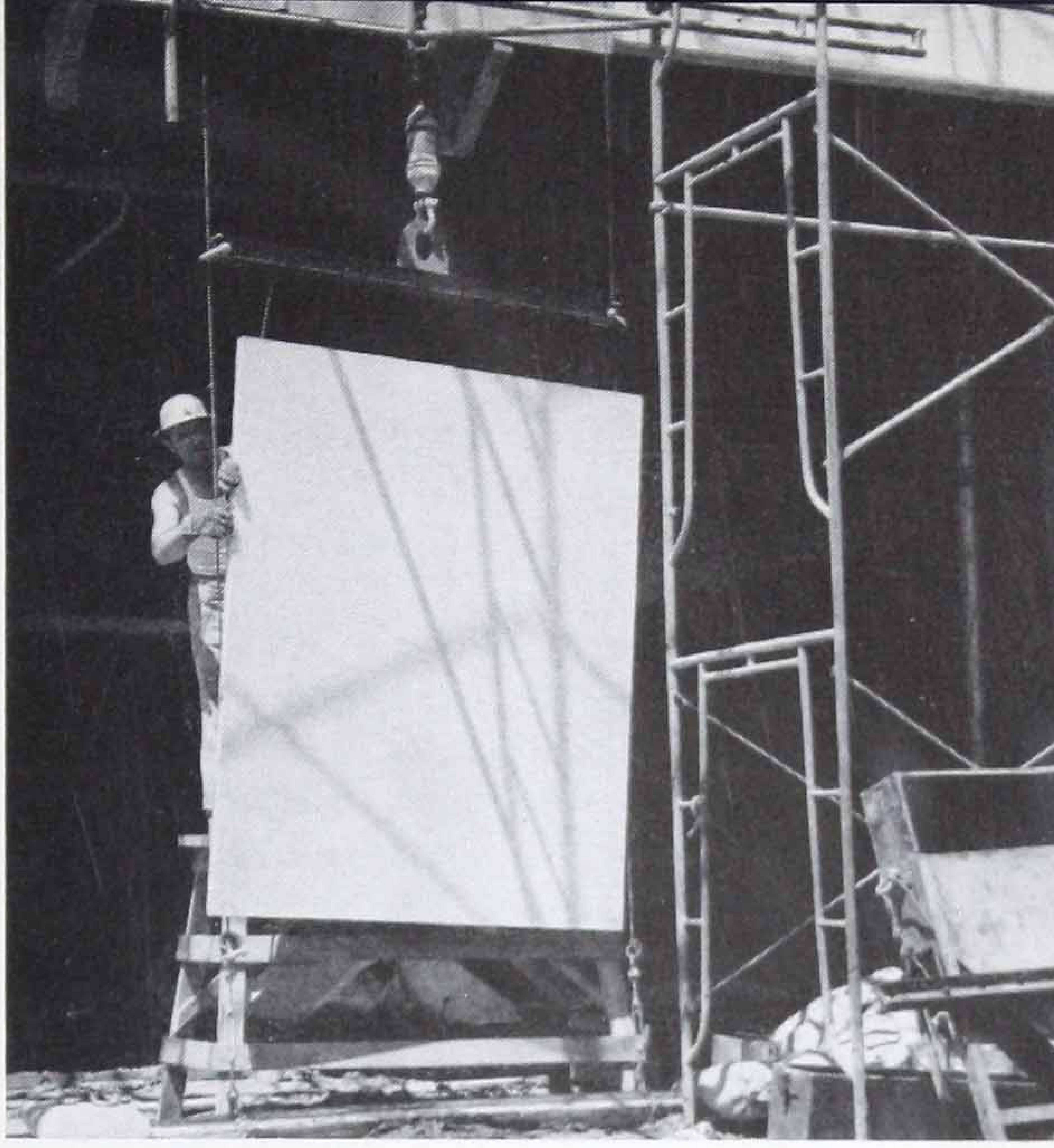
Railway and Highway Uses

An important feature of the precasting of railway and highway structural members is that it greatly reduces the amount of traffic delay and rerouting necessary at the construction site. The replacement of a 50-year-old railroad bridge in New Jersey provides an example of how precasting can speed up this type of construction. The bridge consisted of 8 girders carrying 4 mainline tracks over which nearly 100 passenger trains passed daily. The spans under each of the 4 tracks were replaced on successive days with precast reinforced concrete deck slabs. While the building of forms and casting and curing of the slabs took slightly less than two months, each of the main lines was out of service an average of only 6¾ hours from start to finish of the replacement operation. The average on-the-site construction time for setting the deck slabs was 36 minutes per track.

Similar techniques have been used in several cities and states in the reconstruction or replacement of street and highway bridges. In some instances, small bridges have been precast as complete structures. More common is the use of precast

Left—Precast concrete walls and structural members lend themselves to a wide variety of architectural design. They have found increasing favor for construction of firesafe schools, hospitals, churches and public buildings of many types. Shown here is St. George Church and Rectory in Seattle, Wash., which combines architectural concrete walls with precast bents, precast concrete purlins and precast concrete roof slabs. *Right*—Arches, which were precast in two sections, are being erected.

Precast concrete sandwich wall panels, constructed with a layer of insulation between outer layers of concrete, permit rapid construction and create pleasing interior and exterior wall surfaces. Here a panel is being lifted into position for anchoring to the building frame.



girders, beams, deck panels and curbs used either in combination with each other or with cast-in-place concrete.

Precast concrete piles—some of them longer than the height of a 10-story building—have been used for many years in the construction of trestle bridges (see page 81) and other aboveground structures. Nearly 70 miles of precast concrete piles were used by one railroad in the construction of a single large pier near Norfolk, Va. The piles support a concrete deck 390 ft. wide and 1,100 ft. long, an over-water area of more than 10 acres.

Other uses of precast concrete by railways include slabs for track support, and planks and slabs for construction of grade crossings.

For Houses and Buildings

Of the variety of precast concrete structural members used in house and building construction, perhaps the best known is the precast concrete joist. These lightweight reinforced concrete beams are made in several lengths and thicknesses, and are easily set into place to support either conventional cast-in-place floor and roof slabs, or precast concrete panels or decking, of which there are several types. Also popular are precast concrete steps, which are produced by many concrete products manufacturers.

It is possible to construct virtually an entire building with precast concrete structural members. An example is a school constructed in Bigpine, Calif. After the concrete floor slab had been placed, it was used as a casting table to precast wall panels, roof slabs and arches, which were lifted into place with cranes. Panels were tied together by cast-in-place columns to provide an earthquake-resistant, firesafe building.

portland cement grouting

PORTLAND cement grout is a fluid mixture of portland cement and water, to which fine sand is sometimes added. It has a variety of purposes and is applied in two general ways: by air or hydraulic pressure in pressure-grouting, and by gravity for the construction of certain types of pavement and subballast slabs under railroad track.

In pressure-grouting, the grout is forced under pressure into oil-well casings (see page 109), into the subgrade under track or foundations, and into open joints of old masonry.

In the gravity method, grout is poured and spread over well-compacted aggregate or track ballast, into which it flows until all the voids between the particles are filled. When the grout hardens, the material is bound into a strong mass.

Railway Pressure-Grouting

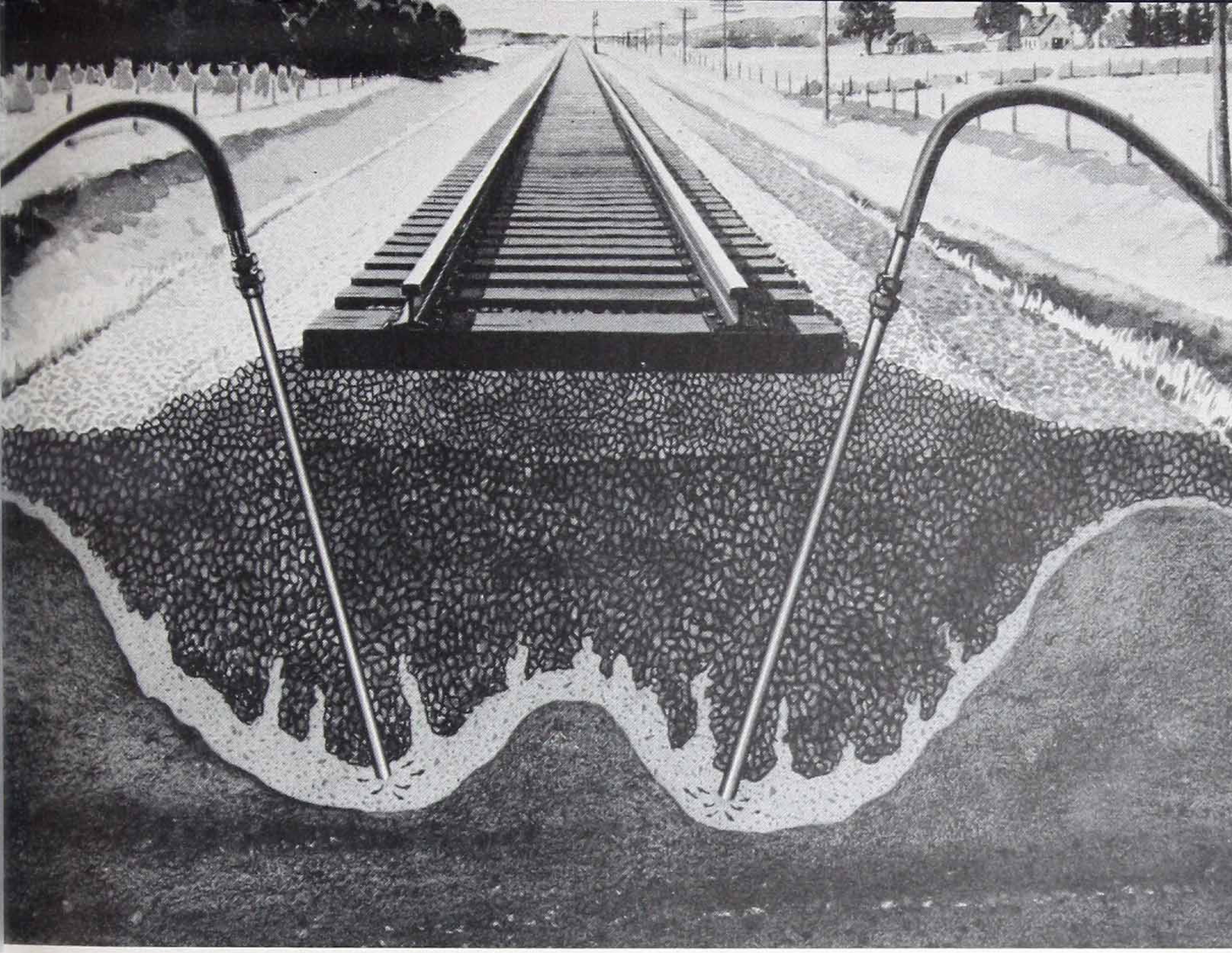
Pressure-grouting is used by the railways in the stabilization of track subgrade, fills and embankments. Track maintenance has long been one of the largest items of expense in railroad operation. Through the use of cement grout, railroads have effected savings of many thousands of dollars in roadbed maintenance, eliminated slow orders and insured more smoothly riding track.

The grout is forced into the track subgrade, displacing air, water or water-saturated material. When the grout hardens, the subgrade is stabilized. If the grout reaches compacted soil that it cannot penetrate, it seals off the mass and protects it from infiltrating water.

Large Savings Effected

In nearly every instance where pressure-grouting has been used by railroads, the entire cost has been returned in savings in maintenance, often in a few months. In one instance maintenance on a section of track cost a railroad company \$100 a month, a figure that was reduced to \$8 a month through the use of pressure-grouting. In another case the same railroad paid for the cost of grouting two sections of track by reduced maintenance expense in 1.3 months. In its first year of grouting, this railroad grouted 13 sections of track, saving \$2,343 in maintenance while spending only \$1,029.27 to do the job.

In Indiana, a New York Central Railroad fill across a swamp required maintenance on the average of one day per week until pressure-grouting was employed to stabilize the marshy subgrade. Maintenance costs on this stretch of track were reduced approximately 95 per cent, and it has been necessary to "resurface" the track only once in five years.



Drawing illustrates pressure-grouting of railway-track subgrade. Cement grout is forced into the subgrade where it displaces air, water and water-saturated material. When the grout hardens, the subgrade is stabilized.

Fifty-five railroads, representing more than half of America's track mileage, today employ pressure-grouting.

Procedure Used in Grouting

The ratio of portland cement, water and sand and the amount of pressure used in pressure-grouting by railroads vary with the condition of the subgrade, but the procedure is basically the same. Injection points through which liquid grout will later be forced into the subgrade are first driven alongside the track, and mixing, distribution and pressure equipment is set up. When a trial consistency of grout has been made, grout lines are connected to the injection points, and the grout is forced under pressure through the lines until it is sufficiently distributed through the subgrade. The pressure required averages about 60 psi (pounds per square inch) and is seldom more than 100 psi.

Of major importance is the fact that pressure-grouting operations do not interfere with normal railroad traffic. Trained gangs can treat several hundred linear feet per day, using the same injection points over and over, while regular rail traffic continues without interruption.

Restoring Old Stone Masonry Pressure-grouting is also employed to restore old stone masonry where mortar has deteriorated or internal cavities have formed. These masonry structures are of two types: those with earth on one side, such as retaining walls or abutments; and those not backed by earth, such as piers and arches.

Usually water is first pumped into the masonry through grouting holes to free channels through which the grout may pass. In restoring masonry with earth on one side, holes are drilled through the wall so that a blanket of grout is formed at the back. Where the objective is to solidify the interior, the holes are drilled to within a short distance of the opposite face. Large retaining walls, arches, bridge piers and abutments are sometimes grouted through holes that are drilled from top to foundation.

The sealing and pointing of joints is usually deferred until the grouting has been completed, in order that vents will be provided for the air and water displaced by the grout.

Grouting Dam Foundations There are two major purposes in grouting dam foundations: to reduce leakage by sealing joints and to consolidate the rock to assure a firm, uniform base for the structure.

Usually grout is injected into the foundation rock of the dam to form a seal or curtain along the upstream face. This curtain of grout is made as nearly watertight as possible, so that there is no seepage through the base of the structure. It also serves to reduce uplift pressure on the dam. In some instances the entire thickness of the foundation supporting the dam is grouted. This is done to assure that there is no variation in the support afforded by the grouted curtain on the upstream face and the remainder of the foundation, and that the load stress of the dam is properly distributed over the entire foundation.

Abutments on either side of the dam structure, and especially the areas around tunnels and intakes, are often grouted to close seams and cracks in the rock.

Gravity-Grouting The gravity method of grouting employed most widely by railways is used to bind the ballast underneath track into a slab that spreads the load over a wider area, to prevent erosion and washouts of embankments and fills, to pave industrial yards, and for various other purposes.

Grouting track ballast requires little specialized equipment. Grout is poured over clean ballast so that it completely fills all spaces between the rock. Excess grout is broomed forward of the pouring, and the ballast is tamped and the grout allowed to harden.

The gravity method of grouting is also used to construct pavements of certain types. The procedure is much the same as that followed in grouting track ballast, except that the subgrade is prepared and forms are set as in conventional concrete construction. Coarse aggregate free of particles less than ½ in. in size is spread and sprinkled with water; the surface is checked with a straightedge before grout is applied. The thickness of the aggregate layer depends on the loads the pavement is intended to carry.

oil-well cementing

OIL is found in certain veins of porous rock, shale or reservoir sands usually located several thousand feet below the earth's surface. In its extraction, casing through which the oil flows must oftentimes be extended downward as far as two miles and more into the earth, passing through formations that may vary from oozing mud and quicksand to underground streams, shifting gravel and exceedingly hard rock.

It is extremely important that the casing be protected against breakage, collapse or corrosion. And since the value of a well is determined by both the quantity and quality of oil produced, it is also important that the oil source be protected against contamination. Portland cement grout, a mixture of portland cement and water, is extensively used today for both of these purposes, and in several other ways in petroleum production.

In the cementing of oil wells, the space between the drill hole and casing is first cleared. This is done by raising the casing a short distance from the bottom of the hole and injecting mud or fluid down into it under high pressure. The pressure forces the mud or fluid from the bottom or open end of the casing, and upward between its outer wall and the drill hole. A stiff portland cement grout is then injected under pressure, which forces out the muddy fluid and replaces it with the grout. As the grout hardens, a protective wall is formed that holds the casing rigid and greatly reduces the danger of its collapse from internal or external pressures. It also seals off corrosive fluids and minimizes water seepage into lower oil-bearing strata.

Pressure-grouting is employed for several other purposes in oil wells. It is frequently used to seal off the bottom of wells where groundwater seepage from below is a problem, and also to plug up portions of a hole when upper strata are found to be more productive or when the hole has deviated so far from the vertical as to make reboring necessary.

do you know that . . .

For the $30 million Folsom Dam near Sacramento, Calif., the project contractors built what is probably the world's largest cooling plant of its type, a $75 thousand refrigeration unit adjacent to the batching plant? The plant, producing 30,000 lb. of flake ice an hour on a continuous basis, was used during mixing to cool the concrete for the dam. Prior to the mixing, aggregates were fanned to lower their temperature.

asbestos-cement products

ASBESTOS-CEMENT building products stem from a discovery by an Austrian, Ludwig Hatschek, who in 1899 developed a process for combining asbestos fibers with portland cement to produce a construction material of high strength and durability, even in relatively thin slabs. This led to the manufacture of the first asbestos-cement product, roofing shingles, in 1905 at Ambler, Pa.

Asbestos-cement products are now made by more than a dozen companies with plants in various sections of the country. Improved manufacturing processes and the introduction of new products such as shingles, wallboard and siding in attractive colors and textures have widened the demand and caused production to increase rapidly. The most recent government figures show that in 1953 the value of production of asbestos-cement shingles, siding, flat and corrugated sheets and wallboard was \$91,212,000—an increase of more than \$34 million over production just 7 years earlier.*

Two Processes

Two processes are employed in the manufacture of asbestos-cement products: "wet" and "dry." The process used depends on the manufacturer and the particular product he makes. All asbestos-cement products are composed of asbestos fibers, portland cement and water, about 75 per cent of the content by weight being portland cement.

In the wet process a pulpy mixture of cement, water and asbestos is formed into sheets that are compressed to remove excess water; after being cut into required shapes and widths, they are subjected to special curing processes.

In the dry process, the portland cement and asbestos fibers are mixed dry and deposited in a uniform layer on a conveyor belt. Water is sprinkled on the layer, and surfacing aggregates (slate, quartz, etc.) are sifted onto it when desired. This layer is compressed into a mat and passed through a high-pressure roll and a cutter roll. The sheets or shingles then receive their final forming under a hydraulic press, and are cured.

Firesafe Siding Shingles

Siding shingles are the largest item of production in the asbestos-cement building-products industry. During recent years manufacturers have introduced these shingles in a wide range of harmonious colors including browns, greens, ivories, and greys in pastels and mellow tones. Some shingles have been striated, which gives them a two-tone appearance.

Asbestos-cement shingles are widely used for siding in the building of new

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*Annual Survey of Manufacturers, U.S. Bureau of Census, 1954.

homes, either alone or in combination with other construction materials, and for remodeling and repair of existing wood-frame houses. They are firesafe and will withstand severe climatic conditions.

Variety of Uses for Board

Asbestos-cement board has a variety of uses, both for exterior and interior construction. Suitable wherever a smooth, hard, impermeable surface is desired, it is used for roof sheathing, for lining walls and ceilings, and for construction partitions. The development of flexible, colored, marbleized and grain-textured boards has resulted in its use for interior decorative effects. Its usual color is a soft grey. It is quickly applied to building frames without the use of special tools. The sheets are usually 4x8 ft. and are available in varying thicknesses.

Roofing Shingles

Asbestos-cement roofing shingles are manufactured in various shapes and colors. One of the newer styles, known as "ranch design," is especially intended for the modern one-story house. Another type, called "strip" or "multiple unit," provides the coverage of from three to five conventional shingles in a single unit. Asbestos-cement shingles are also made in American method, hexagonal and Dutch lap styles to harmonize with the architectural style of any house.

Many old wood-frame homes have been modernized and made more firesafe through use of asbestos-cement siding, roof shingles and other building products, as shown in this before-and-after view of an 80-year-old farm home in Illinois.

portland cement association member companies

Aetna Portland Cement Co.	P.O. Box 392, Bay City, Mich.
Allentown Portland Cement Co.	Seventh St. at Thruway, Allentown, Pa.
Alpha Portland Cement Co.	15 South Third St., Easton, Pa.
Arizona Portland Cement Co.	Rillito, Ariz.
Ash Grove Lime & Portland Cement Co.	101 West 11th St., Kansas City 6, Mo.
Bessemer Limestone & Cement Co.	1100 Wick Bldg., Youngstown 3, Ohio
British Columbia Cement Co., Ltd.	500 Fort St., Victoria, B.C., Canada
California Portland Cement Co.	612 South Flower St., Los Angeles 17, Calif.
Canada Cement Co., Ltd.	P.O. Box 290, Station B, Montreal, Que., Canada
Consolidated Cement Corp.	111 West Monroe St., Chicago 3, Ill.
Kansas Division	618½ Madison St., Fredonia, Kan.
Michigan Division	1003 National Bank Bldg., Jackson, Mich.
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Cumberland Portland Cement Co.	Chattanooga Bank Bldg., Chattanooga 2, Tenn.
Dewey Portland Cement Co.	424 Nichols Road, Kansas City 2, Mo.
Diamond Portland Cement Co.	Middle Branch, Ohio
Dragon Cement Co., Inc.	150 Broadway, New York 38, N.Y.
General Portland Cement Co.	111 West Monroe St., Chicago 3, Ill.
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Signal Mountain Division	531 Volunteer Bldg., Chattanooga 2, Tenn.
Trinity Division	1700 Republic National Bank Bldg., Dallas 2, Texas
Giant Portland Cement Co.	117 South 17th St., Philadelphia 3, Pa.
Glens Falls Portland Cement Co.	Glens Falls, N.Y.
Green Bag Cement Division, Pittsburgh Coke and Chemical Co.	P.O. Box 1645, Pittsburgh 30, Pa.
Hawkeye-Marquette Cement Co.	802 Hubbell Bldg., Des Moines 9, Iowa
Hercules Cement Corp.	1530 Chestnut St., Philadelphia 2, Pa.
Hermitage Portland Cement Co.	American Trust Bldg., Nashville 3, Tenn.
Huron Portland Cement Co.	13th Floor, Ford Bldg., Detroit 26, Mich.
Ideal Cement Co. Divisions	Denver National Bldg., Denver 2, Colo.
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Arkansas Division	611 Wallace Bldg., Little Rock, Ark.
Colorado Division	Denver National Bldg., Denver 2, Colo.
Houston Division	575 San Jacinto Bldg., Houston 2, Texas
Louisiana Division	406 International Trade Mart, New Orleans 12, La.
Montana Division	507 Midland National Bank Bldg., Billings, Mont.
Nebraska Division	680 Insurance Bldg., Omaha 2, Neb.
Oklahoma Division	1018 Cravens Bldg., Oklahoma City 2, Okla.
Spokane Division	724 Old National Bank Bldg., Spokane 1, Wash.
Utah Division	554 South Third West, Salt Lake City, Utah
Inland Cement Co., Ltd.	P.O. Box 555, Edmonton, Alta., Canada
Keystone Portland Cement Co.	1400 South Penn Square, Philadelphia 2, Pa.
Kosmos Portland Cement Co.	1529 Starks Bldg., Louisville 2, Ky.
Lehigh Portland Cement Co.	Young Bldg., Allentown, Pa.
Lone Star Cement Corp.	100 Park Ave., New York 17, N.Y.
Longhorn Portland Cement Co.	1200 Transit Tower, San Antonio 5, Texas
Louisville Cement Co.	501 South Second St., Louisville 2, Ky.
Manitowoc Portland Cement Co.	Manitowoc, Wis.
Marquette Cement Manufacturing Co.	20 North Wacker Drive, Chicago 6, Ill.
Medusa Portland Cement Co.	1000 Midland Bldg., Cleveland 15, Ohio
Missouri Portland Cement Co.	3615 Olive St., St. Louis 8, Mo.
Monarch Cement Co.	Humboldt, Kan.
Monolith Portland Cement Co.	643 South Olive St., Los Angeles 14, Calif.
Monolith Portland Midwest Co.	643 South Olive St., Los Angeles 14, Calif.
National Cement Co.	2144 Highland Ave., South, Birmingham 5, Ala.
National Portland Cement Co.	123 South Broad St., Philadelphia 9, Pa.
Nazareth Cement Co.	Nazareth, Pa.
North American Cement Corp.	41 East 42nd St., New York 17, N.Y.
Northwestern Portland Cement Co.	Northern Life Tower, Seattle 1, Wash.
Northwestern States Portland Cement Co.	Mason City, Iowa
Olympic Portland Cement Co., Ltd.	1425 Dexter-Horton Bldg., Seattle 4, Wash.
Peerless Cement Corp.	1144 Free Press Bldg., Detroit 26, Mich.
Penn-Dixie Cement Corp.	60 East 42nd St., New York 17, N.Y.
Pittsburgh Plate Glass Co. *Columbia Cement Division*	Zanesville, Ohio
Riverside Cement Co.	621 South Hope St., Los Angeles 17, Calif.
St. Lawrence Cement Co.	P.O. Box 1156, Quebec, Que., Canada
St. Mary's Cement Co., Ltd.	2221 Yonge St., Toronto 7, Ont., Canada
San Antonio Portland Cement Co.	P.O. Box 4158, Station A, San Antonio 7, Texas
Southern States Portland Cement Co.	1724 Fulton National Bank Bldg., Atlanta, Ga.
Southwestern Portland Cement Co.	1034 Wilshire Blvd., Los Angeles 17, Calif.
Standard Lime & Cement Co.	2000 First Federal Bank Bldg., Baltimore 3, Md.
Standard Portland Cement Division, Diamond Alkali Co.	105 Union Commerce Bldg. Annex, Cleveland 14, Ohio
Superior-Marquette Cement Co.	50 West Broad St., Columbus 15, Ohio
Superior Portland Cement, Inc.	1003 Seaboard Bldg., Seattle 1, Wash.
Universal Atlas Cement Co.	100 Park Ave., New York 17, N.Y.
Volunteer Portland Cement Co.	P.O. Box 1190, Knoxville, Tenn.
Whitehall Cement Manufacturing Co.	123 South Broad St., Philadelphia 9, Pa.
Wyandotte Chemicals Corp.	Wyandotte, Mich.

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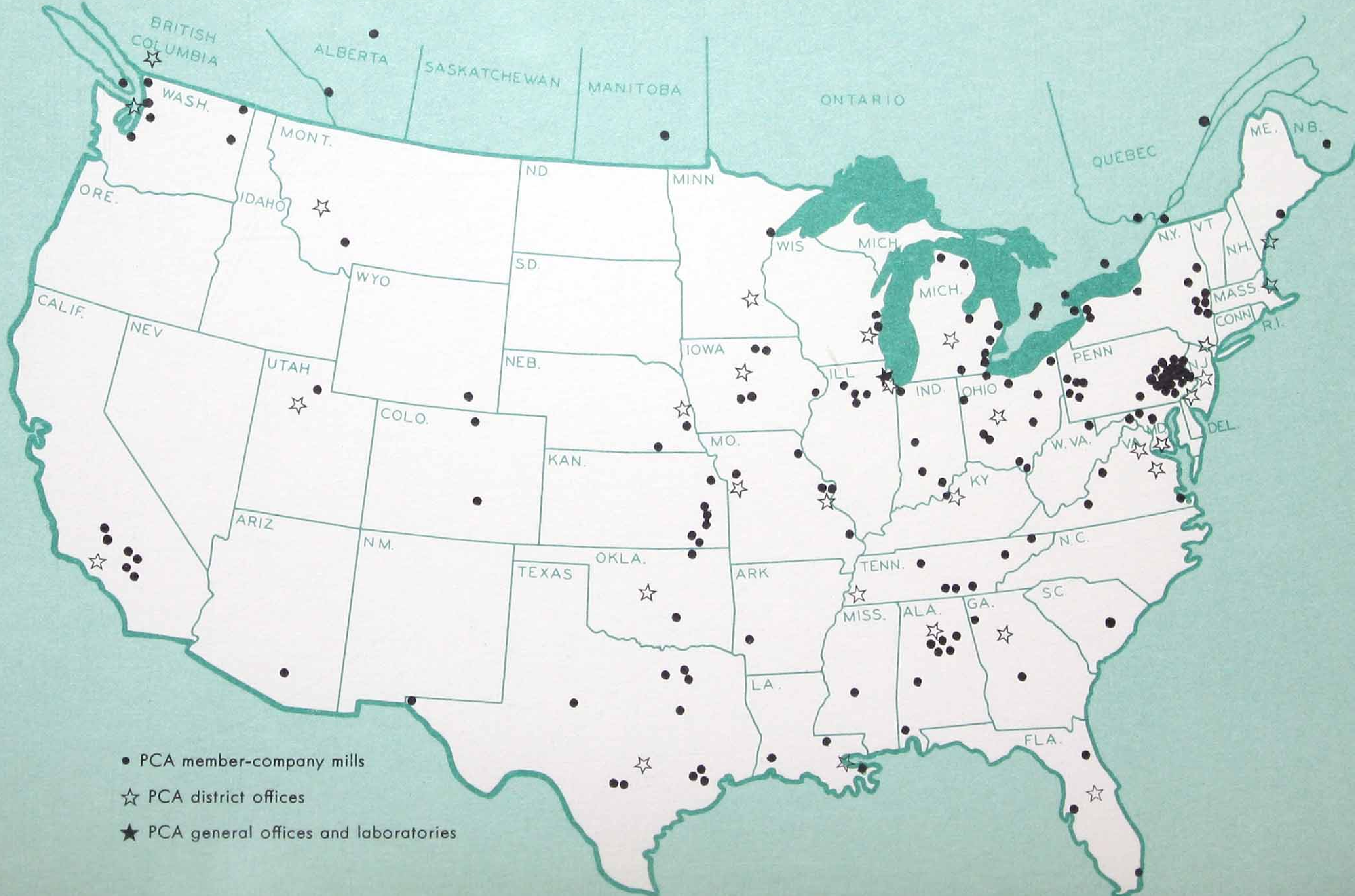

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* concrete pipe
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* manufacture
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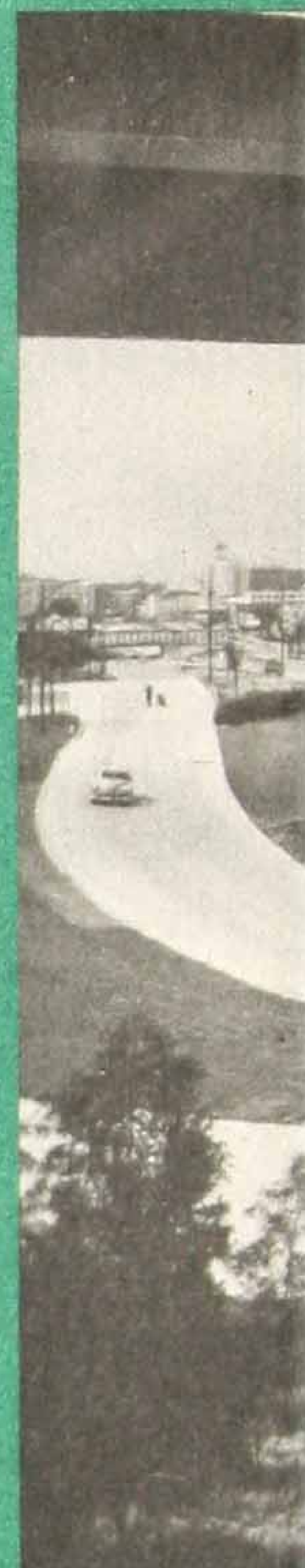

* prestressed concrete
* freeways
* oil-well cementing
* precast structural members
* grouting
* concrete shell roofs
* tilt-up
* concrete bridges
* air-entrained concrete
* early concrete pavements
* cement and concrete research
* highway safety
* concrete masonry
* reinforce
* the highway job ahead
* soil-cement
* railway uses of concrete
* architectural concrete
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